20 YEARS 1872–1992

MAZDA RX-7 VS. CORVETTE LT-1 • PORSCHE 968 • TOYOTA MR2

A Times Mirror Magazine

Popular Science

SNEAK PREVIEW: U.S. CARS TO COME

COMING FROM APPLE

YOUR PERSONAL DIGITAL ASSISTANT

ASTEROID WATCHERS

STATE OF THE ART ELECTRONIC CAMERAS

CRISIS IN EDUCATION Part 2

WHY JOHNNY CAN'T DO SCIENCE AND MATH

SEPTEMBER 1992
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*J. D. Power and Associates® 1992 Light Truck Initial Quality Study. Study based on a total of 10,475 consumer responses indicating owner-related problems during the first 90 days of ownership.
Excludes other GM products. †See your dealer for terms of this limited warranty and Roadside Assistance program details. Chevrolet and the Chevrolet Emblem are registered trademarks and Chevy is a trademark of the GM Corp. ©1992 GM Corp. All Rights Reserved.
Buckle up, America!

Important findings by one of the most authoritative automotive research companies.

Major news for truck buyers! J. D. Power and Associates reports, "Chevy is the new vehicle quality leader in the Full-size Pickup class." In this independent study, Chevy owners reported much higher new vehicle quality than owners of any other full-size pickup.* This is one of the auto industry's largest, most authoritative studies, and now it says what Chevy owners have always known: Chevy is the best full-size pickup in new vehicle quality.

"The best new vehicle quality in its class."

This independent study is the news pickup buyers have been waiting for. Clear, unmistakable results from a comprehensive nationwide quality survey involving more than 10,000 truck owners during the first 90 days of ownership.

The first-time-ever full-size pickup initial quality survey by J. D. Power and Associates, and the results speak for themselves: "Chevy Full-size Pickup has the best new vehicle quality in its class."

st Full-Size Pickup."

ASSOCIATES 1992 Light Truck Initial Quality Study.℠

Chevy is your best buy in a full-size pickup. For all the best reasons.

Chevy's the best. The best resale value. The best standard payload. The best rust protection. The best MPG (EPA Est. MPG city 17, highway 23). All with the biggest V6 you can get, 24-hour Roadside Assistance, and a 3-year/36,000-mile warranty that covers everything, bumper to bumper, with no deductible.† And now J. D. Power and Associates' research confirms what Chevy owners have known all along: For new vehicle quality, "Chevrolet is the best full-size pickup."

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Popular Science

THE WHAT'S NEW MAGAZINE

SEPTEMBER 1992
Founded in 1872/Vol. 241, No. 3

COVER STORY

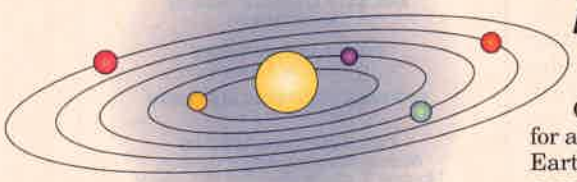
45 Your world according to Newton

As simple to use as a pen and paper, this little black box may be the breakthrough digital information device of the decade. It recognizes your printed handwriting, organizes that information, and stores it in one place. No more misplaced messages, forgotten appointments, or illegible to-do lists.

50 Why Johnny can't do science and math

CRISIS IN EDUCATION Part 2

One educator describes it as "a crisis become chronic": The achievement level of American high school graduates ranks near the bottom of the industrialized world. Poverty, inadequate government funding, and poorly trained teachers are among the causes.



Asteroid watchers 76

Once the sun sets, scientists hunt for asteroids that could collide with Earth—with potentially disasterous consequences. A global telescope network that charts and monitors asteroid orbits is one proposed warning system.

Rocket squad 57

Are today's sports-car makers more concerned with creature comforts than high-horsepower engines? We drove the Corvette LT-1, Mazda RX-7, Porsche 968, and Toyota MR2 on a challenging road course to find out.

62 Digital photography

Filmless electronic cameras allow photographers to meet last-second deadlines and create multiple-image effects, blurring the line further between fantasy and reality in the field of photography.

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COVER PHOTO BY MARC GELLER; GRAPHICS BY TOM WHITE

From The Editor

The sages of Silicon Valley have long forecasted that the "personal" computer of the future will be remarkably different from today's PCs. Alan Kay, one of the founders of Xerox's Palo Alto Research Center in California, conceived the idea of the Dynabook in the early 1980s. About the same time, visionary Ted Nelson updated the concept of a global database with Project Xanadu. And shortly after he took the helm at Apple nine years ago, John Sculley envisioned the Knowledge Navigator.

DOUG MENUEZ

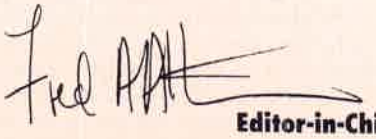
Apple chairman John Sculley and Editor-in-Chief Fred Abatemarco talk about Newton, the Personal Digital Assistant.

Until now, these futuristic ideas have not been much more than that; lots of smoke but no fire to forge the technology that could put the world at our fingertips and make communication and information exchange universally mobile and instantaneous. Now meet Newton, the prototype technology for a new kind of gadget called a Personal Digital Assistant. In this month's cover story, Assistant Editor Marcelle M. Soviero provides a close-up look at the first product of Apple's $20 million-plus research effort and a glimpse at how we may all benefit from a world according to Newton.

How many times have you wished that the geniuses who design computers and software would create something that made it easier—not harder—to master life's details: the random thoughts and ideas, appointments and to-do lists, reminders and messages that so often seem to make or break our day? Newton is a first step. As this technology intersects with the emerging digital world—the inevitable conversion of all written, spoken, photographed, videotaped, and illustrated information into a digital code—we may look back to Newton as a pioneering milestone in the emergence of a host of fantastic information appliances in the 21st century.

Looking ahead in the automotive world, as we've done again this year with our "Sneak Previews of U.S. Cars to Come," our spy photos and off-the-record tipsters reveal an optimistic picture on the domestic scene. The Big Three are getting leaner and their technologies are creating production cars that are literally meaner in terms of beating the competition. Here's where to track your favorite domestic marque and plan ahead for your next car or truck purchase. Next month, we will focus on the imports.

Heard any good "killer asteroid" jokes lately? Recent studies on the subject prompted reactions ranging from angry newspaper editorials to sarcastic cartoon drawings. Skirting these knee-jerk reactions, however, Associate Editor Robert Langreth found some serious science when he visited the Kitt Peak Observatory in Arizona. There, astronomer Tom Gehrels has been carefully documenting the comings and goings of comets and asteroids. Langreth also got a more-than-bargained-for dose of science-after-dark while reporting "Asteroid Watchers." "On the third or fourth consecutive night awake, you enter a zombielike stupor and can confuse even the simplest task," Langreth recalls. "Gehrels read every number out loud before punching it into the computer. It would be embarrassing to think you have discovered a giant new asteroid, only to realize later that you were pointing the telescope in the wrong direction."



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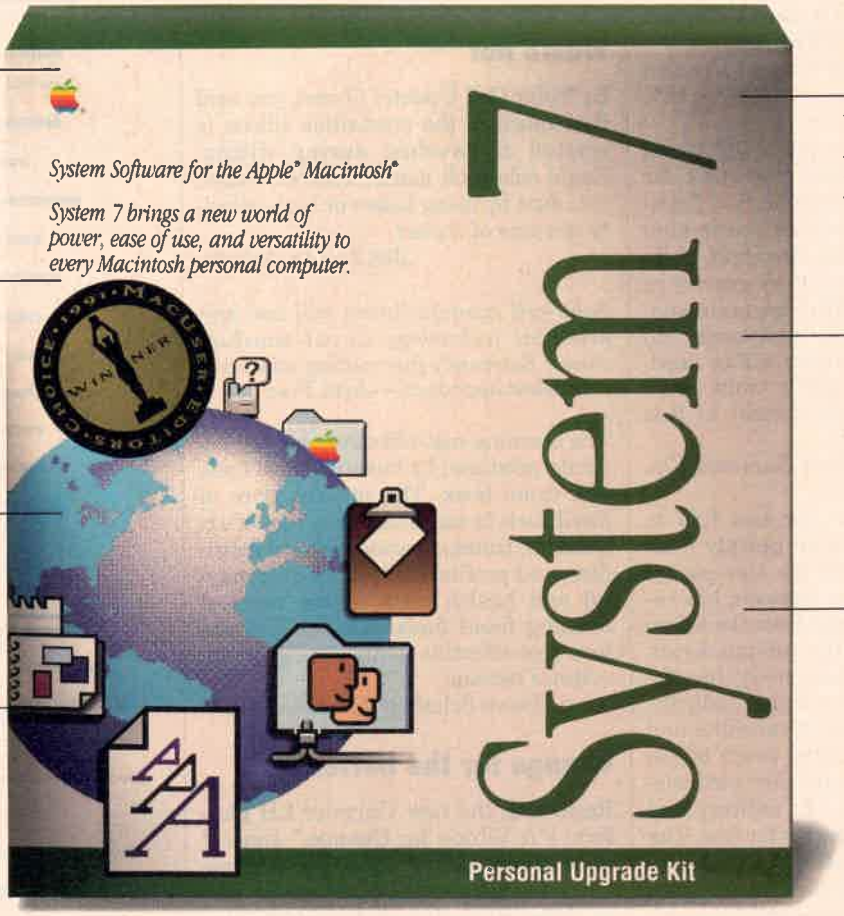
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Readers Talk Back

Rapid response

The map outlining plans for rapid railways across the United States [June] fails to recognize New York's intensive work in this area: Lt. Gov. Stan Lundine has led a multiagency effort that produced a technical and economic analysis of maglev, is evaluating the New York State Thruway right-of-way for these trains, has a high-speed ground transit study for the state under way, and will study alternative high-speed corridors between Boston and New York City.

Donald A. Baker, director
Policy and Program Bureau
Commercial Transport Division
Albany, N.Y.

The ultimate maglev train will travel in an evacuated tunnel that runs, for instance, from New York to San Francisco. The train would be accelerated by gravity during the first half of its journey and decelerated by gravity in the second half. With magnetic suspension and zero air resistance, no propulsive force or brakes will be needed. Theoretically, such a train could traverse a 3,000-mile tunnel in less than an hour.

Gordon W. Kerr, Tequesta, Fla.

High-speed rails use far less fuel to carry more people more quickly than an airplane, and with far less energy used. The technology, however, has received little investment from the federal government and the private sector. Federal transportation policy has favored the commercial airline industry from the beginning, with subsidies and special sales taxes. Plus, much of the construction and propulsion technology was developed by the military and given to the civilian sector for free. The rail-passenger industry has not received any of this largess, resulting in far higher capital costs—and lower returns, which have discouraged private investors.

Gregory B. Warner
Londonderry, N.H.

Term talk

Your statement that the Great Lakes are "the world's largest expanse of fresh water" is incorrect ["Science Newsfront," July]. I have read that Russia's Lake Baikal holds one-fifth of the fresh water in the world and more water than all of the Great Lakes combined.

Gregory R. Blankenship
Sunnyvale, Calif.

"Largest expanse" is accurate, but "largest surface area" might have been clearer. Lake Baikal is deeper than Lake Superior (the deepest of the Great Lakes) and may contain more water than all five Great Lakes. Its surface area (12,700 square miles), however, is much smaller than that of the Great Lakes (94,460 square miles).—Dawn Stover

Waste not

In "Solar Cell Update" [June], you said that much of the crystalline silicon is wasted as sawdust during slicing. Could solar cell manufacturers reduce this dust by using lasers or high-velocity streams of water?

Jon Austin, Atlanta

Solar-cell manufacturers will use any practical technology to cut sawdust waste. Extremely fine cutting wires are one recent approach.—John Free

The seeming cost-effectiveness of electricity produced by burning fossil fuels is a cruel hoax. The market price of fossil fuels is essentially the cost of extraction, transportation, federal subsidies, and profits. Add the environmental and health costs to the price of burning fossil fuels and you will see how cost-effective nonpolluting photovoltaics become.

Steve Schaffer, Brookline, Mass.

Change for the better?

Regarding the new Chrysler LH platform ["A Vehicle for Change," June]: I hope the company's plans include some entry-level, low-priced cars, as opposed to those state-of-the-art excesses covered 12 pages earlier in "Thirty Something." One would think that auto manufacturers would learn to target the growing pool of people with shrinking incomes, and provide vehicles that don't cost two to three years' salary.

Daniel F. Jopp
Spring Valley, Wis.

Address letters to Readers Talk Back, POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016. Or fax your letter to us at 212-481-8062. Letters may be edited for space and clarity. We regret that we cannot answer unpublished letters.

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WHAT'S NEW

EDITED BY MARCELLE M. SOVIERO AND JUDITH ANNE YEAPLE

SUPER SPORTS CAR

Yamaha's Grand Prix SuperCar OX99-11 has the same V12, 3,498cc, DOHC, five-valve engine used on Yamaha F1 racers. The driver sits in the middle of the car, with room—but not a seat—for a passenger behind. Yamaha will make the engines in Japan; the aluminum body will be handcrafted by Ypsilon Technology Ltd. in Britain.

DUAL-MODE 35

A flip of a switch on the Olympus AZ-220 Wide Zoom camera enables photographers to choose between panorama or standard mode even in the middle of a roll of film—the world's first, Olympus claims. The viewing field on the 28-56mm zoom camera also adjusts automatically to ensure accurate composition. The camera weighs 12.2 ounces; price has not yet been set.

EASY TOUCH

Touchmate endows any computer monitor up to 19 inches with touchscreen capabilities. Just place the pizza-size box under the monitor and plug it into the computer's serial port. Price: $895. Visage Inc., 1881 Worcester Rd., Framingham MA 01701.

EXECUTIVE BACKPACK

Now there's no excuse not to bike to work: The Backrider commuter bag, with its tri-fold design, functions as a garment bag to keep your business clothes wrinkle-free. Shoulder straps can also be tucked away and the bag can be carried like a briefcase. The C-420 ($149) holds one suit or dress and has six pockets, two for shoes. The T-1100 ($199) holds enough clothes for three to five days. Enrge Sports Inc., 9 Terhune Dr., Westport CT 06880.

STEADY SCOPE

To block sound or vibrations from its imaging system, the AutoProbe scanning probe microscope has a separate outer shell designed by Lunar Design of Palo Alto, Calif. The computer-driven device, by Park Scientific Instruments of Sunnyvale, Calif., creates images of a sample's surface at the atomic scale.

PARKING DOWN UNDER

Leave your car on a pallet at the entrance to this parking garage and a computer-controlled transporter whisks it to an underground parking spot in just 38 seconds. Tokyo-based Ishikawajima-Harima Heavy Industries Co. claims the garage can be designed to accommodate up to 1,000 cars and can be built for two-thirds the cost of conventional underground garages.

TIME-ZONE TRAVELER

Check the Jet Lag Watch periodically while you're traveling, and you can slowly acclimate yourself to a new time zone. Just input your travel time and the current time at your destination, and when you arrive the watch will have adjusted in small increments to the new local time. Price: $69. The Jet Lag Watch Co., 1193 Walnut St., Suite 8, Newton Highlands MA 02161.

SUNNY-SIDE UP

The Sanyo Solar Egg blimp is powered by the company's own lightweight, flexible amorphous solar cells affixed to its top side. The unmanned blimp and an onboard camera are operated by remote control. Sanyo claims that the craft is the world's first solar airship and intends to use it as a promotional attraction.

MOBILE CD

Nakamichi's 100cdc/i ten-disc trunk-mounted CD changer prevents mistracking. The aluminum chassis and hinged door resist vibration while the airtight door seal eliminates changes in air pressure, which can distort sound. A 20-bit digital-to-audio converter offers enhanced fidelity. Price: $3,000.

TUBE FOR BUS RIDERS

A Brazilian bus shelter collects fares as riders enter it and eliminates the need for stairs on the bus, making entering and exiting the vehicle faster and safer. The glass-and-steel shelters were recently tested in New York City, where they may be installed to encourage urbanites to use public transportation. Specially designed buses with extra-wide doors are needed to mate with the shelters, which cost $30,000 each.

WHAT'S NEW

SOPHISTICATED SEATING

The Evo chair uses just a few major parts made from flexible engineering plastics to achieve ergonomic sophistication. The back, spine, and seat base are molded in one piece from Du Pont Zytel resin that flexes, along with the copolymer C-spring under the seat, to conform to your shape and movements. Price: $500. American Seating, 901 Broadway N.W., Grand Rapids MI 49504.

LOCATER

The Valentine One Radar Locater not only detects four types of radar (X, K, Photo, and Stalker), but tells you where the signals are coming from. Two antennas scan 360 degrees around your car; an arrow on the display points toward the radar. Price: $299. Valentine Research, 10280 Alliance Rd., Cincinnati OH 45242.

CHARTING THE SEAS

Chart Drum Navigator enables mariners to use traditional paper charts with Loran or Global Positioning Satellite navigation systems. The charts slip under a plastic overlay on the drum, which rotates to keep the part of the chart you're using in view; a moving red bead marks your boat's position. The model 1600 holds charts up to 16 by 21 inches and costs $1,599. Chart Drum Corp., 240 W. Andrus Rd., Northwood Ohio 43619.

PERFECT MATCH

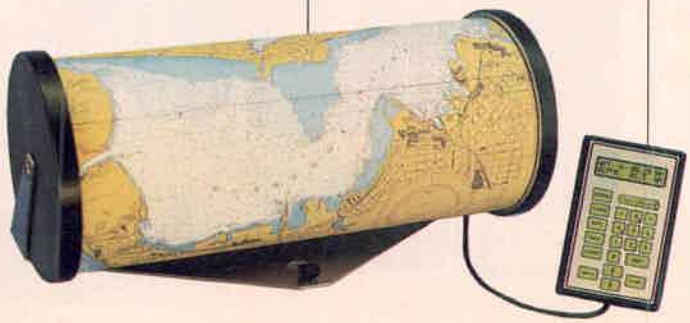
For those who like hearing a pulsating bass guitar when they drive, the 1993 Mazda RX7 offers a unique sound system: Bose's Acoustic Wave speaker technology. A custom-designed waveguide fits in the trunk, providing loud, distortion-free bass and a wide dynamic range.

PC AC

Electronic components run faster when cool, so Sunpower developed a mini-refrigerator to fit inside a personal computer. The $10,000 prototype device uses a Stirling cycle engine that cools without CFCs. Sunpower Inc., 6 Byard St., Athens OH 45701-2702.

WEATHER-PROOF ZOOMER

Protected against water splashed from any direction, the Olympus Infinity SuperZoom 3000 couples a 38-110mm zoom range with predictive autofocus. Other features include an optional wireless remote control and a menu button that displays flash and other options on the liquid-crystal-display panel. The camera costs $450; the remote control is $21.



The bus stops here.

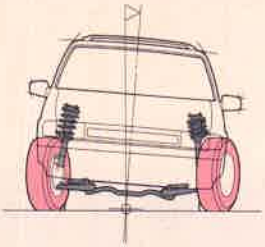
NISSAN

You are part of a generation that has been raised and fed on 0-60 times, horsepower and skid pad

results. And yet for some inexplicable reason, the moment you have kids, car companies expect you to settle for some oversized, ungainly minivan that's about as much fun to drive as a bus.

Well, at Nissan, we believe that parents have enough sacrifices to make. The pleasure of driving shouldn't be one of them. Which is why we designed the new *Nissan* "*Quest*" to be as fun to drive as the sedan you now own.

Slip behind the wheel of the *Nissan Quest* and you immediately notice an absence of the swaying motion minivans are known for. A front stabilizer bar keeps it level during cornering or lane changes. And an independent front suspension allows each front wheel to react independently

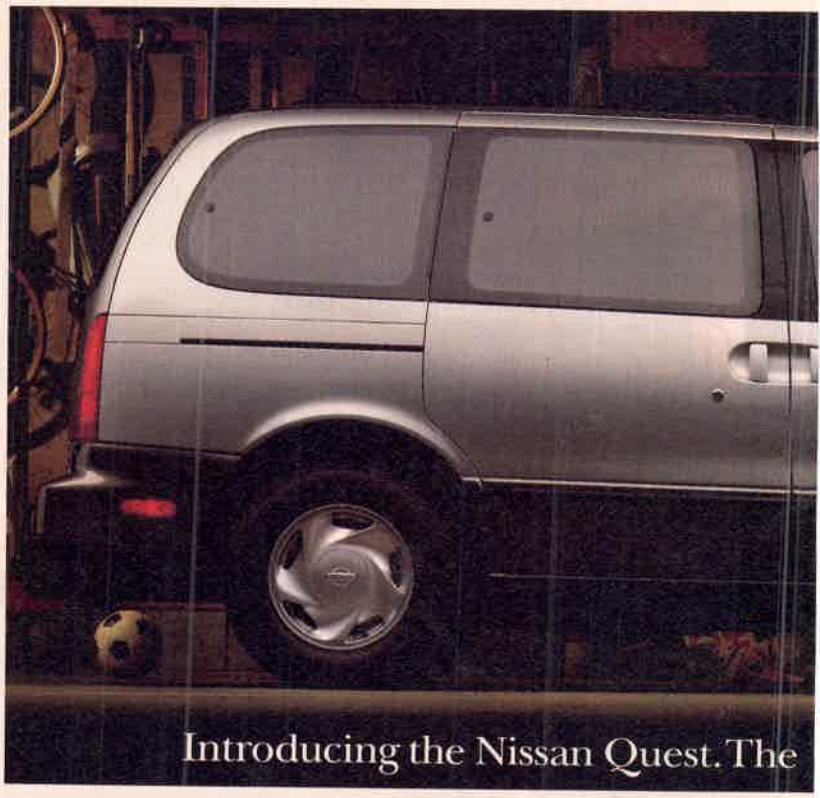


to the road surface for exceptional traction control.

This uncanny feeling that you're driving a sedan is further enhanced by sophisticated front-wheel drive that offers you a tighter and quicker steering response.

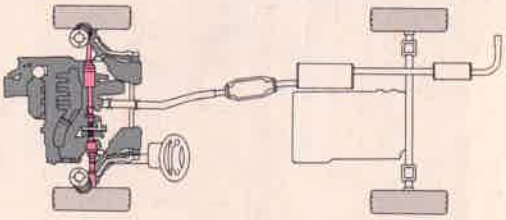
If you think the *Nissan Quest* has an appetite for curves, however, you'll find it's positively famished when it comes to hills. A 3.0 liter V6 overhead cam engine delivers an impressive 151 hp.

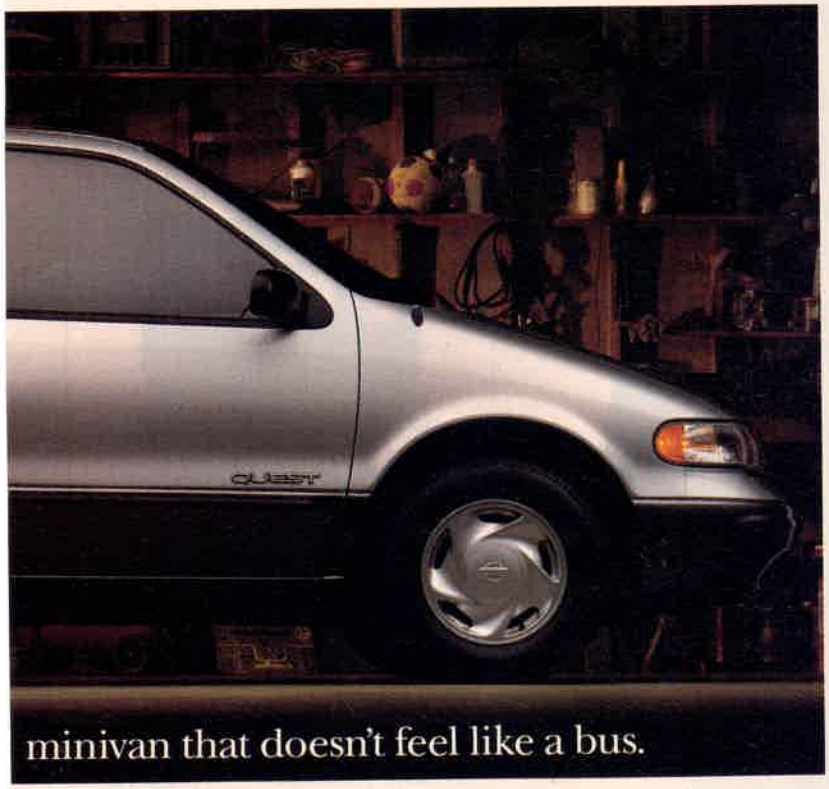
No other minivan has more standard horsepower.* Period. And it's the only import brand minivan to combine both V6 power and front-wheel drive.



Introducing the Nissan Quest. The

But perhaps the most important area where the *Quest* performs like a sedan is





minivan that doesn't feel like a bus.

in safety. For it is one of the few minivans that meets 1993 Federal passenger-car safety standards.**

A day filled with temper tantrums, water balloon fights and potty training, could give anyone jagged nerves, which is why our luxurious interior is designed to soothe and pamper.

Your fingertips settle on a steering wheel graced with fine leather.*** Your eyes gaze at easy-to-read analog instruments. And your ears are lulled by a premium AM/FM audio cassette system.††

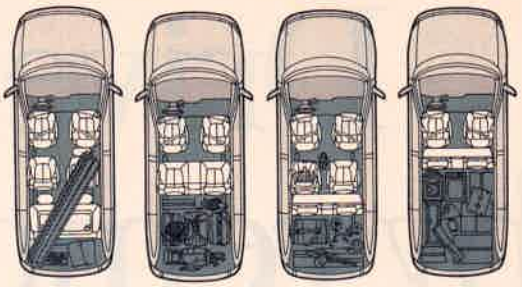
Cruise control† and an optional

sunroof*** are available so you can concentrate on the scenery instead of the speedometer.

Attention to ergonomics is so complete that the controls to the power windows, door locks and mirrors are thoughtfully nestled in the driver's-side door.†

Of course, we intend to spoil your children as well.

A second row of luxurious captain's



chairs††† has been provided to keep your children from

squirming about.

To keep them entertained, the second row even has its own set†† of air conditioning controls, headphone jacks and remote audio controls.

And since we know how much

kids enjoy playing musical chairs, you should know our QUEST TRAC™ Flexible Seating System can be reconfigured up to twenty-four different ways.†††

The new *Nissan Quest* offers better handling and more luxurious comfort than you'd ever expect from a minivan. In fact, it'll make you feel like you're driving a car.

That is, until one of the kids in the back seat throws another temper tantrum.

The New Nissan

Quest

NISSAN

*with privacy glass. ***GXE model. †Optional on XE model, standard on GXE. ††Optional on GXE model. †††GXE with optional 2nd-row captain's chairs.*

Drive a Quest by remote control.

All you need to drive the new *Nissan Quest* minivan is a VCR.

Return the coupon or call 1-800-NISSAN-3 and we'll send you Quest Drive. An exciting driving experience on videotape featuring remarkable innovations your whole family will enjoy. Free.

But, hurry. These tapes may go faster than the minivan itself.

The New Nissan Quest

NISSAN

1-800-NISSAN-3
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Yes. Please send me a free Quest Drive videotape.

Name

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We have (number) ____ vehicles. They are (make, model, year):

The vehicles I am considering include (make, model, year):

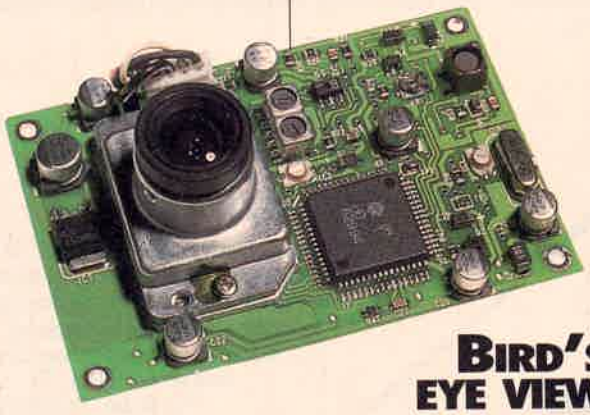
For additional information, please call 1-800-NISSAN-3, ext. 132.

Quest Drive, c/o PCCI
P.O. Box 91-1190
Commerce, CA 90091-1190

WHAT'S NEW

LUXURY WAGON

Britain's Astin Martin claims its station wagon is the fastest dedicated load carrier in the world—and priced at $280,000, it's also the most expensive. The coupe-based Virage Shooting Brake is powered by an all-alloy 5.3 liter, four-cam, 32-valve V8 that delivers 330 hp for a 152-mph top speed and 0-to-60-mph acceleration in 7.6 seconds.

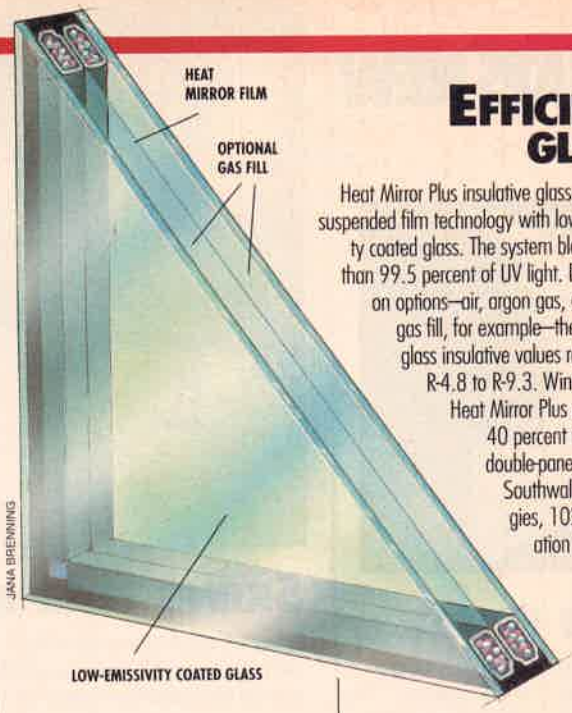


BIRD'S EYE VIEW

This miniature 1.3-ounce videocamera, shown at actual size, can be mounted on the wing of a model airplane or used as part of a security system in your home. Real-time pictures can be viewed on a TV when the camera is used with a transmitter and receiver (not included) or wired directly to the set. The model PC-3 costs about $190. Supercircuits, 13015 Debarr Dr., Austin TX 78729.

SEE-THROUGH SPEAKERS

The lead crystal spheres of Clearball speakers optimize sound reproduction and add a decorative touch to any interior, says developer Sasaki Glass Co. The 9.4-inch-diameter CB250-DX (right) costs about $700 in Japan. Other models and colors are available in the Clearball series.



JANA BRENNING

EFFICIENT GLASS

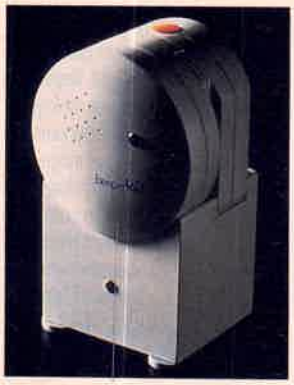
Heat Mirror Plus insulative glass combines suspended film technology with low-emissivity coated glass. The system blocks more than 99.5 percent of UV light. Depending on options—air, argon gas, or krypton gas fill, for example—the center of glass insulative values range from R-4.8 to R-9.3. Windows with Heat Mirror Plus cost 20 to 40 percent more than double-pane windows. Southwall Technologies, 1029 Corporation Way, Palo Alto CA 94303.

TWO-WAY PAINTER

The pad on the Simple Solutions Corner Painter flexes, so inner and outer corners can be painted with the same tool. Price: $4; replacement pads are $1.50. EZ Paintr, The Newell Group, 4051 S. Iowa Ave., Milwaukee WI 53207.

QUICK AND COMFORTABLE

The Norwegian UT-904 ferry combines the speed of a catamaran with the smooth ride of a hovercraft. Two fans beneath the craft create a five-foot air cushion that is trapped by the twin hulls and rubber skirts at the bow and stern, enabling the slim hull tips to slice through the water with little drag. Top speed of the 128-foot-long, 360-passenger ferry is 50 knots (about 57.5 mph). Ulstein International AS, N-6065 Ulsteinvik, Norway.



KID FINDER

BeeperKid, a child monitor/locating system based on radio frequency technology, sounds an alarm when a child strays farther than 30 feet. To help find the child, the parent activates an alarm on the child's device. Price: about $99, including a recharging stand. A&H International, 737 Bishop St. Suite 2400, Honolulu HI 96813.

PRIVACY, PLEASE

The Escort 900 MHz digital phone has a half-mile range and is the first consumer cordless to incorporate spread spectrum technology, which offers increased privacy and little interference. It costs $249 and weighs about a pound. Cincinnati Microwave, Escort Division, 5200 Fields-Ertel Rd., Cincinnati OH 45249.

SKIING YEAR-ROUND

Enthusiasts can ski year-round at the Ski-Inn Tsudanuma, a man-made slope housed in a dome just outside Tokyo. To avoid melting problems, the "snow" is actually a synthetic resin. The ski slope is intended for beginners only; it measures 130 yards long and has a maximum slope of just 13 degrees.

MUSICAL HYBRID

What do you get when you cross a violin with a guitar? The Viotar, a six-string instrument played with a bow that has a neck strap to hold it up slightly higher than a guitar, leaving your left hand free for playing. Marketing plans and price have not yet been set. Bob Schlink, 78 Priscilla Ave., Providence RI 02909.

TWO-SPORT CAR RACK

Allsop's Access Sports Rack holds four bicycles or, with an optional attachment, six pairs of skis. The rack's swing arms pivot down and away so the vehicle's storage compartment can still be accessed, even when the rack is fully loaded. Rack: $290; ski attachment: $160. Optional hitch and cable locks are also available. Allsop, Inc., Box 23, Bellingham WA 98227.

COMFY CUTTERS

Large, padded handles and a built-in spring that separates the blades after each cut make these scissors easy to use and comfortable for those who lack strength in their hands. Designed for either left- or right-hand use, the scissors have stainless steel blades and a sliding lock for storage. Price: $20. Fiskars Inc., Box 8027, Wausau WI 54402.

SEAWORTHY SLR CASE

Owners of autofocus SLRs can photograph the underwater world with the help of the Ewa Marine Model U-AX housing. Made of thick, two-ply PVC plastic and stainless steel with an optical-glass port, the U-AX housing accommodates a variety of cameras with a flash attachment. Price: from $159 to $229. Pioneer Research, 216 Haddon Ave., Westmont NJ 08108.

COSMIC DESK SET

Toshiba's Galaxy Collection of desk accessories combines functionality and a futuristic look. The collection includes a thin-cutting letter opener ($40), pencil sharpener with safety feature ($60), ink and pencil eraser ($40), and vacuum-type desk cleaner ($40). The curvaceous collection runs on AA batteries. Toshiba America Consumer Products, 82 Totowa Rd., Wayne NJ 07470.

QUICK BBQ

Bar-B-Brics have a thin layer of an ignition agent so they light quickly and reach cooking temperature within three minutes without giving food a chemical taste. Made of clean-burning anthracite coal, the bricks meet California's air quality standards. Each burns for two hours; a box of five bricks costs $5. Future Fuel Ltd., 9420 Santa Anita Ave., Rancho Cucamonga CA 91730.

HIGH-TECH HOT ROD

The one-of-a-kind Mitsubishi Aluma Coupe combines the styling of a traditional American hot rod with modern innovations like electronic fuel injection, microprocessor-controlled ignition, and Mitsubishi's two-liter, four-cylinder GS Turbo engine. Hand-built by independent designer Boyd Coddington, the aluminum-bodied car produces 375 hp and also includes a four-wheel independent suspension.

Model LA 132

Traffic Laser Is Here ...And So Is Your Best Defense.

Introducing BEL LaserAlert

There has been a lot of talk lately about laser traffic monitoring. Briefly, police laser guns measure the speed of moving vehicles by projecting an invisible beam of intense, infrared laser light – as opposed to conventional radar microwaves.

The bottom line is this: laser is being used right now. And since conventional radar detectors don't detect laser, you need to supplement your overall protection capability.

From Success In Desert Storm To You

In developing BEL LaserAlert, we searched for the most sophisticated laser detection technology – and found it protecting our air and ground forces in Operation Desert Storm. In partnership with Tracor Aerospace – a major manufacturer of defense electronics – we adapted this patented, proven military technology to consumer laser detection.

That's why BEL LaserAlert provides laser detection that's ***up to ten times the effective range of police laser guns.*** This unprecedented sensitivity even detects "off-axis energy" – where the main laser beam is scattered by physical or atmospheric conditions. And BEL's sophisticated LSV (Laser Signal Verification) eliminates false alerts.

BEL LaserAlert Features

- **Unprecedented detection range of over 5 miles**
- **Stand-alone operation, or connects with most radar detectors**
- **Smallest laser detector – weighs only 2.25 oz.**
- **Patented, proven military technology**

BEL LaserAlert Operates With Most Radar Detectors

As a micro-sized, 2.25 ounce stand-alone unit, BEL LaserAlert provides unmatched laser detectability. When linked to a BEL Radar Detector you have an unbeatable combination of laser and radar protection. In fact, using our convenient power jack adapters, BEL LaserAlert can be linked to most popular brands of radar detectors for laser/radar capability.

Full Protection Demands BEL LaserAlert

No matter what radar detector you are using now, adding BEL LaserAlert will provide total protection.
BEL LaserAlert is available today for $119.95

To order or for the name of a dealer near you, call toll free:
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BEL LaserAlert
Model LA 132

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Science Newsfront

Edited by DAWN STOVER

External burning

Aerodynamicists conducting computer simulations and wind-tunnel tests on scale models of the experimental X-30 National Aerospace Plane have identified an area of low pressure behind the craft that markedly increases its drag during acceleration through the speed of sound and up to about Mach 3 ["X-30: Out of This World in a Scramjet," Nov. '91].

This so-called drag hump in the plane's aerodynamic efficiency curve is bad news. It means the X-30 would have to carry extra-powerful engines just to push through the transient drag, then be overweight for the rest of the flight once it attained high Mach speeds and low Earth orbit.

Flight testing to find a possible solution to the drag problem will begin next summer at NASA's Dryden Flight Research Facility in Edwards, Calif. The idea is to pump hydrogen fuel *outside* the engine exhaust nozzles so that it trails into the hot exhaust plume. Researchers hope that external burning will increase the air pressure aft of the engines, thereby reducing the efficiency-robbing drag.

External combustion is a ripe old idea; steam locomotives have always relied on it. Aircraft propulsion systems that burn fuel externally have been studied for several decades too. In fact, the method could already be in use on secret military aircraft. Nighttime observers in desert areas of California and Nevada have spotted extremely fast, high-flying aircraft that glow brightly, suggesting that external combustion may provide part or all of their propulsion at supersonic speeds.

The "engine" for such an aircraft may consist of a cone-shaped exhaust nozzle defined by the plane's tapered tail area and by shock waves trailing back from its nose during supersonic flight. Fuel sprayed from the craft's aft surface ignites in the hot, highly compressed airflow. The resulting gases generate thrust as they expand through the nozzle area.

NASA will conduct its X-30 research using one of its three SR-71 Blackbirds, the only members of the legendary spy-plane fleet still in service. A 12-foot model of an X-30 exhaust nozzle will be mounted atop the SR-71's fuselage, where it will gather data on hydrogen's susceptibility to flaming out in the fast-moving airstream, and measure turbulence that may be generated by the burning process. Sensors in the exhaust plume area will monitor temperature and pressure levels.

A series of about 16 test flights are planned at speeds exceeding Mach 3 (about 2,000 mph). The program seeks to determine whether an external burning system would be smaller and lighter than giving the X-30's primary propulsion system enough thrust to push it over the drag hump. —*Stuart F. Brown*

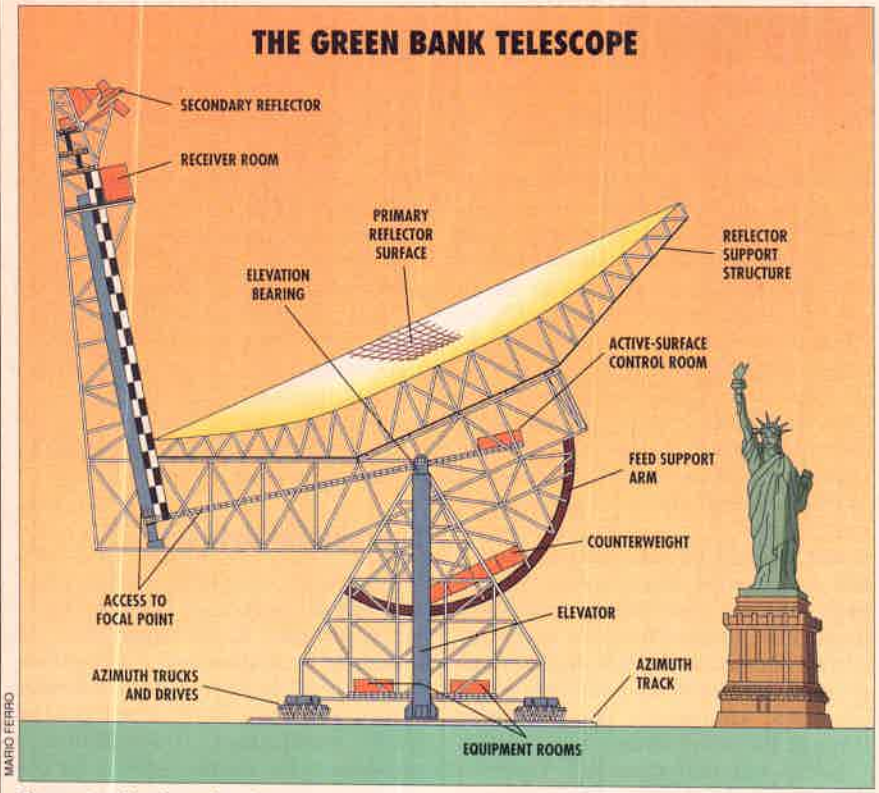
Salmonella detector

When the Food and Drug Administration asked Los Alamos National Laboratory physicist Roger Johnston to find a way to spot salmonella contamination in eggs, he turned to a colleague whose expertise is in arms control treaty verification. Dipen Sinha, a physicist at Los Alamos, uses sonic resonance to detect chemical and biological warheads in artillery shells. With minor changes, the technology can also be used to pinpoint bad eggs.

According to Johnston, the detection method is a high-tech version of thumping melons. The scientists place an egg between two piezoelectric transducers, one acting as a speaker

An exhaust nozzle for the experimental X-30 aircraft is mounted atop an SR-71 in this artist's concept. The SR-71 will serve as a test bed to validate the concept of externally burning hydrogen to reduce drag.

NASA



The receiver for this radio telescope is mounted on a sidearm, so it does not block incoming signals. This drawing shows the size of the telescope relative to the Statue of Liberty.

and the other as a receiver, and then connect the apparatus to a computer. A normal egg resonates with a single, sharply peaked wave on the monitor. But the vibration pattern for an egg injected with *Salmonella enteritidis* bacteria has two waves, one tall and one short.

Johnston says a commercial salmonella detector could be engineered very easily. It would fit inside a small case and would probably cost less than $200.—*Ray Nelson*

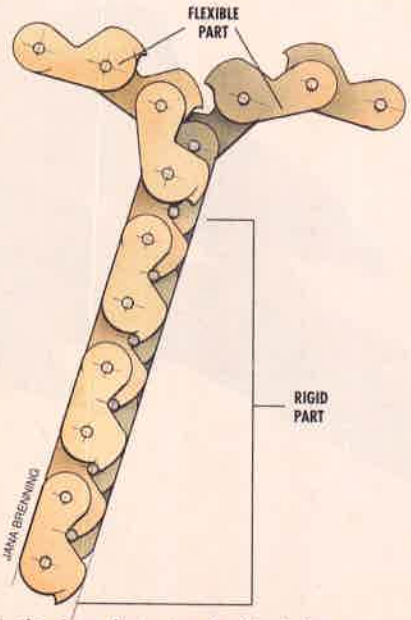
Sidearm scope

A new instrument under construction at the National Radio Astronomy Observatory in Green Bank, W.Va., will be the largest fully steerable radio telescope in the world when it is completed in 1995. The $75 million Green Bank Telescope will replace a 300-foot radio telescope that collapsed in 1988. It will be used to study pulsars, quasars, and other astronomical phenomena.

According to project manager Robert D. Hall, the 328-by-367-foot disc will feature an unobstructed aperture made possible by a special sidearm configuration. In a radio telescope, a large antenna collects radio waves and focuses them onto a receiver—usually suspended above the center of the antenna by a feed support. "Our feed support is to the side," says Hall, "so nothing is obstructing the path of the incoming radiation." That should help the telescope detect weak signals.

The new telescope will be able to swivel in all directions. One set of drives will make the antenna pivot on a bearing, controlling its elevation. Another set of drives will rotate the entire telescope on a 210-foot-diameter circular steel track, controlling its azimuth. The telescope's predecessor moved only in one direction, scanning the sky along a north-south line; astronomers had to rely on Earth's rotation to move the telescope along an east-west line.

The Green Bank Telescope will be the first of its type to have an adjustable surface: Computer-controlled actuators will move the 2,006 aluminum panels at speeds up to ten thousandths of an inch per second, continuously compensating for surface distortions caused by gravity, wind, and thermal effects. Actuators have previously been used in optical telescopes to correct for atmospheric distortions.—*Patricia Barnes-Svarney*



In this clever device, two flexible chains are "zipped" together to form a rigid support.

Zip-lock chains

Reshape the links of two bicycle chains so they lock together like a zip fastener to form a rigid support. That's the idea behind a Swiss concept that transforms a pair of flexible chains into a solid bar, using a simple guide block and motor-driven sprocket, or just a pair of pinch rollers.

The invention, called a Transformable Structure Element, could be used to extend and support a window blind or awning. It could be a radio mast rising from a car roof, a flagpole, a hidden security barrier at an airport, a jack, an elevator mechanism, or even a spreading device for solar panels on a spacecraft. Unlike telescoping devices, the transformable element occupies no working area when retracted; the two chains can slide, curl, or fold up into any convenient space.

The trick is the clever geometry of the links, which have a hooked leading tip and a central notch. The links of each chain are joined by projecting hinge pins. When the two chains meet, the tips of the links on one chain hook over the leading pins of the other chain. As the chains move farther, the central notches seat the trailing pins. This sequence is repeated on alternate sides as the two chains interlock.

All of the links are identical, so tooling and production costs would presumably be low. The links could be made in any size and material. Materials might even be mixed; a few nylon links could serve as insulators in a metal chain, for example. Another possibility is a curved support to extend around corners, achieved by slightly altering the links' hook position in one chain.—*David Scott*

Superior timber

From the deep, chilly waters of Lake Superior, Scott Mitchen pulled an unusual treasure: massive logs of century-old virgin timber.

"We were actually looking for shipwrecks," explains Mitchen, whose Explorations International of Washburn, Wis., specializes in archaeological recovery and education. "But I always saw all these logs down there. The bottom is covered with pine, hemlock, maple, birch, walnut, everything." One day, he recalls, a lumberman told him of their value, and Mitchen resolved to bring up the old wood.

Huge, century-old logs at the bottom of Lake Superior yield near-perfect lumber.

Tens of thousands of logs sank in the lake during turn-of-the-century lumber operations, says Mitchen. The three- to four-foot-diameter timber is knotless and fine-grained from slow growth—properties almost unknown in lumber today. Although waterlogged, the lumber interiors were well-preserved by low oxygen levels and temperatures of 35°F to 37°F.

To reclaim the wood, divers move the logs to shallower water with inner tubes and air bags; then a barge and crane take over. When it is cut open, says Mitchen, "the wood looks like the day it went down."

Mitchen says the wood's history sparked his imagination. "This is a time capsule of the first and very best wood that was cut. There are stamps from the mills on the end of the logs," he says. He plans to recreate a working 1870s-type sawmill camp and museum. A modern mill will cut the wood for artisans to make items such as replicas of antique furniture. "There's wood down there, such as elm, that really doesn't exist anymore. Shipping it out to have studs made is out of the question," Mitchen adds.

But Mitchen, who estimates that there are some 20 seasons' worth of lumber in the lake, is in no hurry. "We don't want to clear-cut the bottom, so to speak."—*Mariette DiChristina*

Healthy air

Despite assertions that the American public believes the government imposes too many unnecessary regulations, a recent survey finds that 80 percent of Americans support stronger car emissions standards, 92 percent favor cleaner-burning gasoline, and 86 percent would limit pollutants from consumer products such as paint, aerosol sprays, and pesticides.

These are the findings of a nationwide survey conducted by the Gallup Organization for the American Lung Association. The survey also revealed that 87 percent of adults believe air pollution is a serious problem. Yet only 38 percent say air pollution poses a serious threat to their own health, a result John D. White, president of the American Lung Association, finds "disturbing."—*Arthur Fisher*

Wind trials for super span

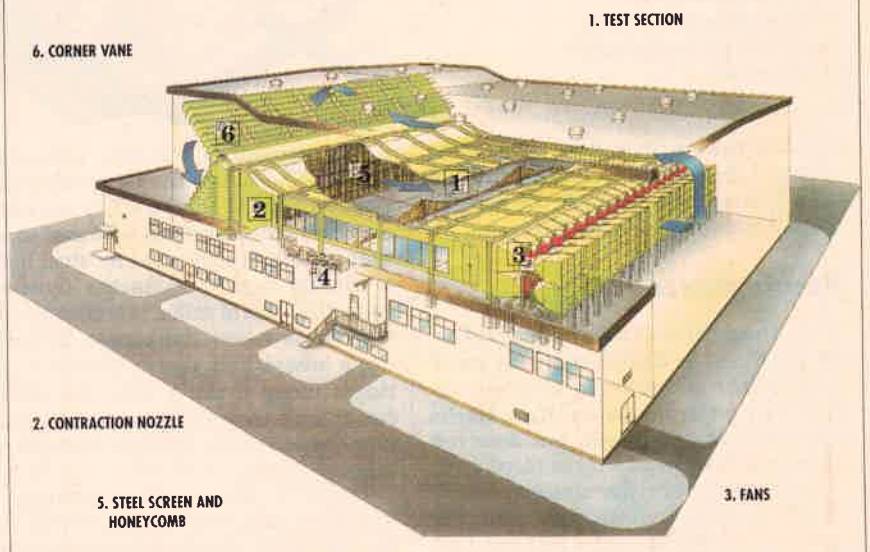
Three new suspension bridges with record-setting spans will be erected by the end of the decade. The Tsing Ma Bridge, part of Hong Kong's Lantau Fixed Crossing, will have a center span of 4,692 feet when it opens in 1997. That same year, Denmark hopes to complete the East Bridge, with a main span of 5,328 feet. And in 1998, Japan plans to open the Akashi Kaikyo Bridge, with a center span of 6,529 feet. Although longer bridges are being considered, the Akashi Kaikyo Bridge is likely to hold the record for some time. Britain's Humber Bridge, with a span of 4,626 feet, has been the world's longest since 1981.

Even as the piers for the Japanese bridge are being built, researchers are investigating the structure's response to wind loads at the new Boundary Layer Wind Tunnel Laboratory in Tsukuba, Japan. The huge facility was built specifically for testing bridge models. To accommodate a 100-to-1 scale model of the Akashi Kaikyo Bridge, researchers required a laboratory floor that is spacious enough for two full-size tennis courts.

As air flows through the lab in a circular pattern, the movement of the bridge model is tracked by video cameras trained on infrared-light-emitting diodes attached to the bridge's deck and cables. The cameras are connected to computers that calculate the amount of movement and the vibration patterns.

Researchers use an airflow of 28 feet per second to simulate the 280-foot-per-second typhoon winds predicted to occur once every 150 years at the bridge's site on Japan's Inland Sea.

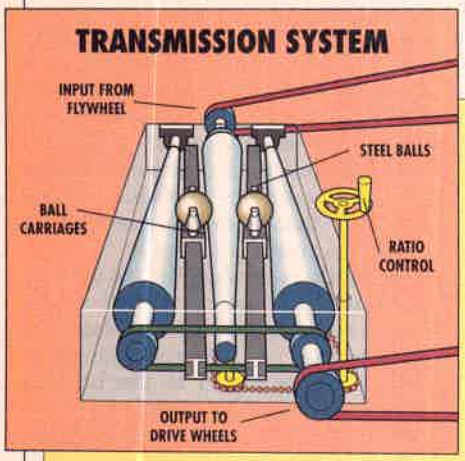
TUNNEL-TESTING A BRIDGE

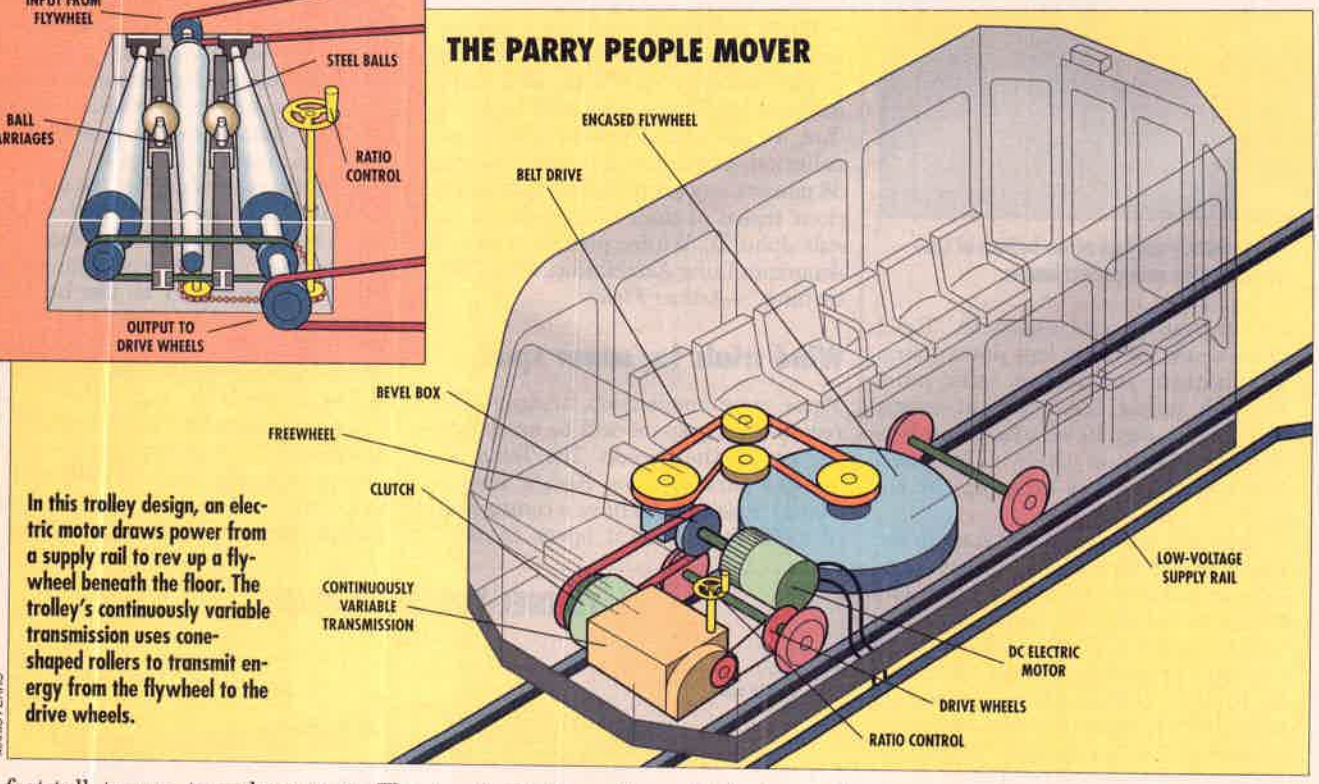


In this Japanese wind tunnel, three dozen large fans located at one end draw air through the test chamber. The air circles back through a plenum above the chamber ceiling. At the other end of the lab, vanes and screens direct a uniform flow of air back through the test chamber.

The tiny typhoon blows the model's deck out of alignment, and makes the whole structure quiver and shake. "Of course," says Yasuji Saeki, chief of the facility, "the bridge would be closed to traffic during high winds."

Years of computer simulation and tests of bridge sections have led to the selection of a 46-foot-deep stiffening truss girder to support the bridge deck and its six lanes of highway traffic. Pendulum-like tuned mass dampers will also be suspended within the 975-foot-tall towers to reduce sway. The current wind-tunnel tests, scheduled to take 18 months, will verify the bridge's overall stability.—*Dennis Normile*




THE PARRY PEOPLE MOVER
ENCASED FLYWHEEL
BELT DRIVE
BEVEL BOX
FREEWHEEL
CLUTCH
CONTINUOUSLY VARIABLE TRANSMISSION
LOW-VOLTAGE SUPPLY RAIL
DC ELECTRIC MOTOR
DRIVE WHEELS
RATIO CONTROL
In this trolley design, an electric motor draws power from a supply rail to rev up a flywheel beneath the floor. The trolley's continuously variable transmission uses cone-shaped rollers to transmit energy from the flywheel to the drive wheels.
MARIO FERRO

People mover

A flywheel-driven trolley designed by an enterprising British company could help reduce air pollution in urban areas. The trolley runs on steel tracks and uses electric power, but does not require an overhead wire or third rail.

To demonstrate the concept, Parry People Movers built an eight-seat prototype that operates on a 260-foot loop track at the company grounds near Birmingham, England. A 12-seater will soon be running on a half-mile circuit at a nearby municipal park.

"The layout is simple, deliberately low-tech," says John Parry, the company's chairman. Under the floor of the 11-foot prototype, a 440-pound flywheel is encased in a mixture of hydrogen and helium—gases lighter than air and therefore less resistant to the flywheel's rotation. The trolley stops for 30 seconds at each passenger loading station, where a short supply rail feeds power to a ten-horsepower electric motor that spins the flywheel up to 4,500 rpm.

The supply rail is not dangerous to people or pets, Parry claims, because it operates at low voltage. Conventional electrified rail systems operate at high voltage to avoid transmission losses over long cable runs.

A continuously variable transmission (CVT) couples the flywheel to the trolley's wheels. The CVT is an ingenious device consisting of three cone-shaped rollers separated by steel balls in sliding carriages. As the flywheel spins the central roller, it transmits energy to the rollers flanking it. By turning a wheel that moves the ball carriages along a chain loop, the driver can change the ratio between the rotational speed of the flywheel and the rotational speed of the trolley wheels.

The CVT also controls braking: If the driver progressively lowers the ratio, the drive wheels turn faster than the flywheel can spin. Thus the flywheel retards the car, and in the process recovers energy. At the last moment, the driver decouples the flywheel drive and brings the car to a halt with friction brakes.

While the trolley has a calculated top speed of 50 mph, Parry says it will be limited to about 18 mph in public service, averaging perhaps half that on typical stop-and-go runs. With a maximum flywheel storage capacity of two kilowatt-hours, the recharging stops could be up to three miles apart, with each one fed from local power sources. Parry sees his people-mover as a low-cost, clean alternative to the minibus, diesel railcar, and urban light railway, with applications such as links from parking lots to airports, suburban shopping malls, and theme parks. —*D. Scott*

Plastic from plants

The best way to make peace between plastic and the environment? Grow the stuff out of the ground. That's what scientists at universities in Michigan and Virginia are beginning to do, employing the same genetic engineering techniques used to build better vegetables.

The researchers have introduced a gene into *Arabidopsis thaliana*, a relative of the mustard plant, that induces it to make plastic resins from the chemical building blocks of its oils. The material, called polyhydroxybutyrate (PHB), resembles polypropylene. Unlike its petroleum-based counterpart, however, PHB degrades naturally in soil, and its manufacture produces no pollution.

The gene that triggers polymer production was taken from a soil bacterium, where it is found naturally and

has the same effect. A British company is already using bacteria-produced plastic to make biodegradable shampoo bottles. The process is expensive, however: Bacterial PHB costs about $12 a pound versus 50 cents a pound for petroleum-based plastic.

Christopher Somerville, a botany professor at the Plant Research Laboratory run by Michigan State University and the U.S. Department of Energy, envisions introducing the plastic-making gene into a productive agricultural crop like potatoes. Granules of PHB could be extracted from the potato in much the same way starch, which is chemically similar, is now extracted. "Most plants that produce potentially useful oils are not adapted to agricultural practices," says Somerville, "so we want to use genetic engineering to bring a few genes from those wild plants into our agricultural species."

On a related front, James Crivello of Rensselaer Polytechnic Institute in Troy, N.Y., is doing chemically what Somerville's team is getting plants to do genetically. Crivello has come up with a plant-oil-soluble photo-initiator: a catalyst that turns plant oils into plastic when exposed to ultraviolet light. The technique seems to work well on the oil of *Vernonia galemensis*, a plant considered a weed in Kenya. —*Ellen Muraskin*

Nonstick coating

Dow Chemical Co. scientist Donald L. Schmidt held up a sample of Formica and drew a felt-tip marker across it several times. Dark lines appeared on half of the sample; on the other half were beads of liquid that Schmidt wiped off easily with a dry paper towel. The second half, he said, had been treated with a new nonstick, non-stain coating.

"Things just don't adhere to it," says Schmidt, who performed the demonstration in April at the American Chemical Society's annual meeting.

Unlike most nonstick coatings, which are made from solvents that can be damaging to the environment, the new coating is water-based. Sprayed or brushed onto a surface, it forms a soaplike film that bonds tightly to the surface as it dries.

The new material, a fluoroacrylate, could be used as a topcoat to protect cars from insects and dirt. It might also be applied to countertops, furniture, and wallpaper. In urban areas, it could defend subway cars against graffiti.

Dow plans to license the formulation to coatings suppliers. Products using the formulation could be available as early as next year, Schmidt predicts. PS

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THE REINTRODUCTION.
And here it is. The 1992 Ford Taurus. An innovative wonder that gives refinement and subtlety their due. The new Taurus has a completely redesigned exterior that gives you a distinct new edge of sophistication. The interior is quieter, more comfortable. And the instrument panel flows smoothly from door to door, with controls put in places that will pleasantly surprise you.

THE SAFETY STORY.
But this Taurus is not just a testament to smoothing rough edges. It's taking the best of new ideas and putting them to use. Anti-lock brakes are available. And Taurus offers *dual air bags* (standard driver and optional right-front passenger air bag supplemental restraint system to be used with your safety belts)—a Ford Motor Company exclusive in this class.

THE SATISFYING CONCLUSION.
The 1992 Ford Taurus. An excellent reminder that the best sequels are the ones that know why the original was a success.

NEW TAURUS Ford

Automotive Newsfront

Edited by DAN McCOSH

Return of the trolley

While auto makers scramble to develop the ultimate battery, a Minnesota-based inventor claims to have found an electric vehicle solution that uses no battery at all.

Nick Musachio of St. Paul, Minn., says his electric cars will cruise at 65 mph with unlimited range, easily power air conditioners, and tow any weight. What's more, he says his technology would eliminate the massive toxic waste problem often associated with batteries.

What is Musachio's ground-breaking new invention? It's a 1990's adaptation of a technology that has served cities for decades. The E-Tran system, as it's known, uses a street-mounted cable to supply energy to a vehicle powered by an electric motor. Unlike subways or 1940s-type trolley cars, however, the system does not use a third rail or overhead wires to supply the power. Instead, it operates solely from a two-inch-wide street cable, which is activated only when an E-Tran car passes over it. As a result, pedestrians can step on the cable without danger.

To achieve that, E-Tran employs magnetic proximity sensors to identify the presence of magnets on board the vehicle. A solid-state relay then energizes the portion of the power strip adjacent to the car.

Floating trolleys, mounted near the front and back of a typical car, act as positive and negative contacts to the electrical line. Used in combination with the cable's "linear commutator" design, the car's trolleys always contact a positive and negative wire simultaneously, providing drivers with greater mobility than traditional streetcars or subways. Since the new trolleys are designed to be as wide as the car, drivers are permitted a full car-width of lateral movement over the electrical line.

The University of Minnesota's Center for Transportation Studies has funded a study to develop the concept, including a hybrid-drive version that would use a gasoline engine to power the car when it leaves the electric cable. The U.S. Department of Energy (DOE) also is sponsoring a technical evaluation of E-Tran at the Idaho National Engineering Laboratory. "It's a viable technology," says the DOE's Dana O'Hara. O'Hara stresses, however, that the technology requires significant further evaluation.

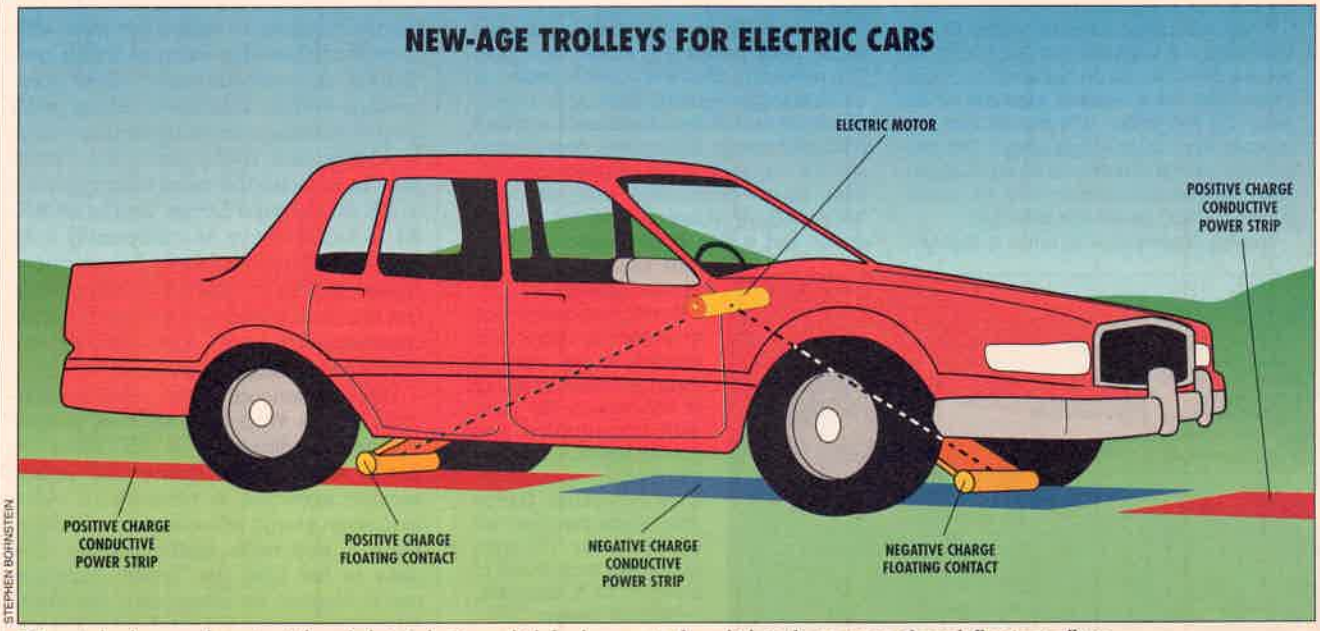
A short ride in a crude demonstration vehicle revealed some obvious limitations. It was easy to jump the "tracks," particularly in corners, and the steering was stiff to begin with. The next step is to develop a full-size car with on-highway capabilities. *—Chuck Murray*

TravTek's computer screen displays information on destinations and navigation.

Travel advice

The promise of numerous on-board navigation systems being tested around the world may not be so much finding out where you are as discovering where you want to go. Global Positioning Satellites (GPS) and various dead-reckoning systems have been demonstrated in many cities, but integrating them with a comprehensive information database has been slow in coming.

One of the most comprehensive and

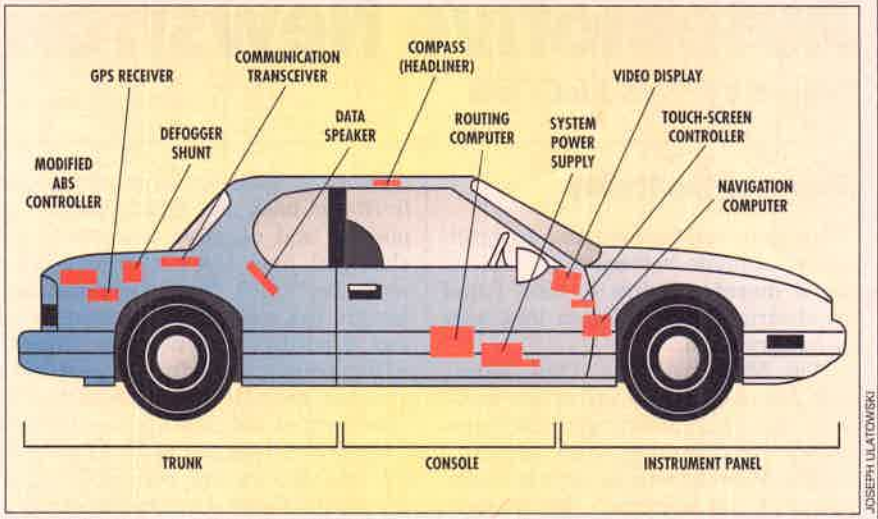

NEW-AGE TROLLEYS FOR ELECTRIC CARS
ELECTRIC MOTOR
POSITIVE CHARGE CONDUCTIVE POWER STRIP
POSITIVE CHARGE CONDUCTIVE POWER STRIP
POSITIVE CHARGE FLOATING CONTACT
NEGATIVE CHARGE CONDUCTIVE POWER STRIP
NEGATIVE CHARGE FLOATING CONTACT
STEPHEN BOHNSTEIN

E-Tran technology employs street-based electrical strips, which feed power to the vehicle's electric motor through floating trolleys.

complex travel information and navigation systems in use anywhere became operational this spring in Orlando, Fla., where co-sponsors General Motors and AAA Motor Club have begun testing TravTek units, designed to provide real-time traffic and navigation assistance. So far about 100 have been installed in a rental fleet of 1992 Oldsmobile Toronados, most of them leased to members of AAA.

The system features a computerized information catalog containing a wide variety of goods and services, including restaurants, hotels, specialty stores, and flea markets. All information can be called up on an on-board CRT screen that has an accurate positioning system and traffic reporting network. Though it is comprehensive, it's also complex—hence sometimes unwieldy to use, as we discovered after living with a TravTek-equipped car for three days in the Orlando area.

The casual observer will first notice a small, somewhat odd-looking antenna mounted next to the rear deck. This satellite receiver is linked to a GPS network more than 10,000 miles in space, which helps determine the vehicle's location. This task is shared by a high-tech dead-reckoning system that uses an electronic compass combined with turn and speed data from the vehicle. TravTek currently relies more on the ground-based system, but engineers say that's likely to change as additional satellites are deployed.



The complex navigation system combines communications and position-sensing equipment.

After starting the engine, logging onto the computer requires just a touch of a button. The menu that pops onto the screen includes route selection, access to a yellow pages directory, and information on area restaurants, hotels, attractions, and special events.

Programming a destination is easy although somewhat time-consuming. TravTek can either guide you to a numerical street address or a particular intersection. Despite the fact that 32 frequently visited locations can be stored in the memory, it generally requires two keystrokes for each letter or digit. Thus there may be a two- to three-minute delay between turning the key and getting under way.

The system relies on two 386 PC-type computers to select the most efficient route based on current traffic conditions. A synthetic voice offers step-by-step verbal directions, along with ample warnings about upcoming turns, accidents, and traffic jams. For example, "In nine-tenths miles turn right onto SR-50 Colonial Drive. Traffic on SR-50 Colonial Drive is moderately congested." The dashboard computer screen scrolls an electronic map while the car is in motion, showing the adjacent street grid with a purple line representing the suggested route.

Information on traffic flow is gathered from a variety of sources, including vehicle detectors in 250 intersections, reports from police and public service agencies, a network of video cameras along often-crowded Interstate 4, and radio traffic reports. The data is fed into the Traffic Management Center in downtown Orlando, which transmits a digital signal to the cars. "We are still in the process of de-

P R E V I E W D R I V E

UNLEASHED VIPER

Chrysler built the outrageous Viper to cast a reflected glow of performance and glamour onto its entire lineup. The auto maker has already succeeded in this, while provoking the ire of some efficiency-minded folks appalled at Viper's thirst for fuel (13 mpg in the city/22 mpg on the highway). But the 196 customers paying $55,000 or more to own first-year editions can rest assured that the Viper's provocative, macho form gets looks from almost everyone.

When production versions of the Dodge Viper became available late last spring, we spent a 500-mile day on highways and racetracks with the fourteenth example off the assembly line to see how the car had progressed from its prototype stage. The two-seater's central attraction is its eight-liter engine, which produces a claimed 400 horsepower and 450 pound-feet of torque.

The big aluminum V10 emits a curiously flat, droning exhaust note, like a pair of four-cylinder pickup trucks with leaky mufflers. Oceans of torque are available at almost any engine speed, making the six-speed gearbox seem superfluous. In top gear at 80 mph the motor spins at just 1,600 rpm.

Control feel in general is linear, as it should be in a fast sports car. The non-ABS brakes are powerful, provide the driver with good feedback, and are easy to modulate during hard use.

Fit and finish of the virtually handmade plastic body panels and interior are good. The removable cloth roof—clearly added as an afterthought—seems destined to eventually shred itself in the wind stream and take permanent leave. Folding this infernal thing into the tiny trunk is an exasperating business. Austin Healey-style removable vinyl "side curtains" (there are no roll-up windows), and a lack of air-conditioning (until next year) complete the austere package.

During high-speed runs at a remote desert test location, it was easy to reach an indicated speed of 155 mph in fifth gear, with acceleration and rpm to spare. The listed 165 mph top speed is entirely believable. Dodge also claims the Viper will accelerate to 100 mph and brake back down to zero in 14.5 seconds. —*Stuart F. Brown*

veloping the best way to handle the traffic information that comes into the center," according to GM project manager Jim Rillings. "We need to determine how much weight to assign the different sources of traffic information—how slow or heavily congested does a road have to be before we send information to the cars. We're still tuning the system."

Test-driving in the Orlando area is expected to continue through March of next year. "We're trying to get objective measures of the time that people can save in their travel by having navigation information and real-time traffic updates in their cars," according to Rillings. "The Federal Highway Administration estimates that something like 15 percent of all travel is wasted because of poor choice of route. That's a lot of driving, a lot of fuel, and a lot of emissions that really don't do anybody any good."

Based on our three-day test drive, TravTek is off to a good start but is far from perfect. The system generally worked well, but lost track of its location four times—usually when the car was near airports, amid heavy congestion, or near other likely sources of radio and magnetic interference. It once

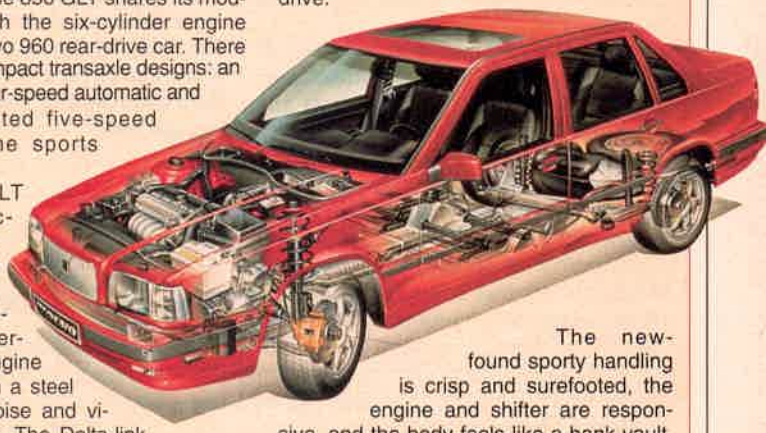
P R E V I E W D R I V E

VOLVO'S FIRST FRONT-DRIVER

An all-new sports sedan from Volvo, the 850 GLT is Volvo's first front-drive car available in the United States. It's powered by a transverse 2.5-liter, five-cylinder in-line engine with a four-valve-per-cylinder design and dual-path induction that makes 168 hp at 6,200 rpm. The 850 GLT shares its modular design with the six-cylinder engine found in the Volvo 960 rear-drive car. There are two new compact transaxle designs: an Aisin-Warner four-speed automatic and a Volvo-patented five-speed manual for the sports sedan crowd.

The 850 GLT uses a MacPherson-strut front suspension with offset coil springs. Rack-and-pinion steering and the engine are mounted on a steel subframe for noise and vibration isolation. The Delta-link rear suspension design combines semi-trailing arms and a beam axle in one unit, providing a degree of passive rear-wheel steering through its mounting bushings.

The roomy, airy interior of the new 850 offers comfortable long-distance seats, a tight array of basic instrumentation along with a digital information center, and an outstanding level of power-train quietness, especially considering that it's front-wheel drive.



The new-found sporty handling is crisp and surefooted, the engine and shifter are responsive, and the body feels like a bank vault, but the engine could use another 40 pound-feet of torque to maximize the fun. Prices for the 850 GLT will start at about $25,000.—*Jim McCraw*

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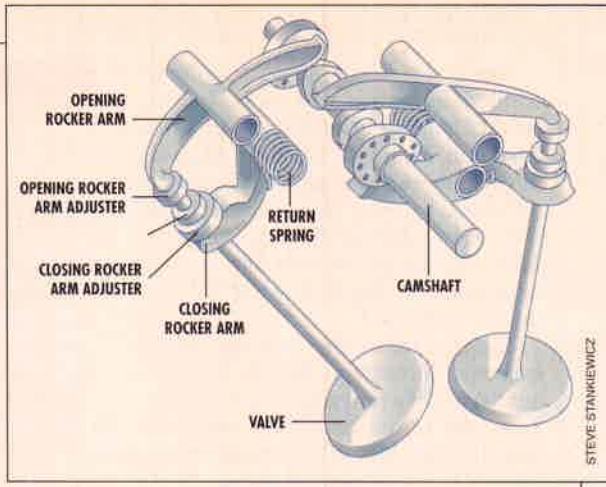
Poulan PRO
The Pro Approach

became so disoriented that it briefly reported we were in a completely different section of town. Engineers say that the navigational problems should subside when the system becomes more dependent on the satellite data as opposed to the compass.

While the transmission must be in "park" to use many TravTek functions, it is easy to become focused on the computer screen and forget that you're driving a moving vehicle. The distraction factor would probably diminish, though, as the novelty of the system wears off.

A number of glitches must be fixed before the product is ready for market. Nonetheless the system is very impressive. TravTek is at its best with medium- to long-range city navigation rather than over-the-road driving or quick runs to the grocery store. It's anticipated to be on the market by 1994 with widespread use by the turn of the century.—*Ken Presti*

Scant bodywork shows off the engine and chassis of the trim 750 SS (above). The Japanese Showa front fork is an upside-down type using large, non-sliding upper tubes.



Ducati's desmodromic valve-actuation system uses separate cam lobes and rockers to open and close each valve. A small return spring holds the valve tightly closed against its seat. Shim-type adjusters provide correct free-play between components.

Desmodromic Ducati

The Ducati motorcycle is one of the few engines in regular production using positive cam actuation to both open and close valves. Called the desmodromic actuation system, Ducati's complex design employs an overhead-camshaft-and-rocker arrangement to operate each cylinder's pair of valves, without using conventional coil springs.

The mid-1950s creation of engineer Dr. Fabio Taglioni, Ducati's desmodromic mechanism overcame problems with valve-spring metal that fractured in high-rpm racing engines. Mercedes-Benz briefly used similar valve gear in racing cars during the same era, but abandoned it when metallurgists developed new steel alloys for valve springs and advancing knowledge about cam-profile design permitted a return to coil springs. But Ducati never backed away from the maintenance-intensive system, which serves as its technological calling card. Though most engine designers consider it mechanical overkill, the belt-driven "desmo" setup succeeds in reliably opening and closing the valves with a minimum amount of friction and has become a cult article of faith among many owners.

We spent 1,200 miles astride a new 750 SS, Ducati's lightest model at a featherweight 388 pounds. Its appearance is a breath of fresh air in an era when so many makers have succumbed to the vogue for gumdrop plastic bodywork that hides a cycle's mechanical heart. The 750's striking white-enameled frame is a triangular lattice made of chrome-moly, the steel alloy used in racing bicycles.

The narrow engine is cooled by oil that is pumped around jackets cast into the cylinders, then through a finned radiator mounted in the airstream. A 90-degree V-angle gives the motor perfect primary balance, with secondary vibration pulses that are low in frequency and untroubling to the rider. Ducati tunes the short-stroke power plant for a broad band of mid-range torque, with an extra surge of power

P R E V I E W D R I V E

THAT OPEN-AIR FEELING

The new Honda Civic Del Sol's removable roof panel and power-operated rear window give the car an open feeling—minus the abuse inflicted on a ragtop driver's ears and hair in the wind stream. The quietness and absence of buffeting are truly impressive, making conversation possible in an almost normal tone of voice.

Built on the fourth-generation Civic chassis, the Del Sol is available in an S-model with Honda's 1.5-liter, 102-hp engine, and a sportier Si model with the 1.6-liter, variable-valve-timing engine. Honda wisely elected not to bring stateside the gimmicky power-roof option offered on Japanese and European models of the car ["ANF," June].

The space saved provides trunk capacity sufficient for luggage. The Del Sol's 23-pound aluminum roof panel slides into a well-designed rack in the trunk lid. When stowed, it uses up about two cubic feet of space.

The rear roof support in the Del Sol helps banish rattles and flexing. An extra set of heater vents thoughtfully located thigh-high on the center console provides a cocoon of warmth for roofless motoring when it's chilly outside.

This departure from the original Honda CRX offers a roadster-ish alternative in harsh-weather regions, where a traditional convertible is hard to justify.—*S. F. B.*

available near the 9,000-rpm redline.

The motor pulls agreeably when required, reducing the need to change gears. Its considerable compression braking makes it easy to follow a hilly route with only occasional braking.

At $7,350, the medium-powered 750 SS is Ducati's entry model. More money buys bigger engines with features such as Weber-Marelli electronic fuel injection, liquid cooling, and four-valve cylinder heads. The truly exotic limited-production machines at the top of the line deliver very high performance with only a modest weight gain. Today's Ducatis are the two-wheeled equivalents of Ferraris: sophisticated yet elemental, beautifully crafted, and exhilarating to ride. They sell briskly in Japan at almost twice the American price.—*S. F. B.*

This self-cleaning highway reflector warns against icy road conditions.

Icy-road warning

The reflective studs that mark the center line and edges of a darkened road at night are an unlikely place to find a high-tech advancement, but a new device invented in Britain promises to supersede the old design.

New silicon-filled reflectors change colors when the temperature drops below freezing, warning drivers that the road is becoming icy. These reflectors also incorporate an ingenious mechanism that acts like a tiny windshield wiper, cleaning dirt from the lenses.

The unit's self-cleaning system works by the expansion and contraction of a temperature-sensitive silicon fluid that operates a tiny piston. The piston drives a ratchet mechanism that slowly rotates a cylindrical lens against a wiper blade. A gap behind the lens is filled with clear fluid. When the temperature falls below 35°F, the silicon fluid drops below a critical volume and a film of dyed alcohol is drawn into the gap behind the lens tube. This changes the reflected color to blue, warning the driver of possible black ice.—*David Scott* PS

TEAMWORK

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Electronics Newsfront

Edited by JOHN FREE

Digital audio war

A battle between two new audio formats is slated to get under way this fall. One technology, the digital compact cassette (DCC), borrows features from the ubiquitous compact tape cassettes. The second, a mini-disc (MD) format, is a spinoff from compact discs. Both are being touted as the next-generation audio format. And both deliver digital sound quality combined with the ability to record.

Proponents of the new digital tape cassettes stress their "backward compatibility" ["The Second Coming of the Digital Cassette," June '91]. You won't have to toss your analog cassettes in the trash because DCC machines can play the older tapes. Backers of the recordable 2.5-inch mini-disc emphasize the portability of MD hardware, the split-second access to music bands, and its ability to resist skipping even when used while jogging ["Pocket-Size Recorder Plays Music on a Mini Disc," Aug. '91]. Despite similarities to standard CDs, though, mini-disc machines won't play the five-inch audio discs.

Both formats use special digital encoding techniques for recording and playback. Music sound patterns are analyzed during recording and audio signals that are inaudible to most humans or those masked by louder sounds are discarded. This filtering technique and further electronic compression eliminates 75 percent or more of the information contained on a CD. During playback, the sound quality of the decompressed audio is comparable with but not quite equal to that of CDs.

Both DCC and MD machines contain a serial-copy-management chip that enables you to make one copy of a CD, but blocks duplication of that copy. Federal legislation pertaining to royalties and copyrights for digital recordings is still being debated. A pending bill would require an add-on fee for machines, discs, and tapes. The money would compensate copyright owners for rerecordings.

This October, the first DCC record/playback decks for home use will be available. DCC machines from Technics, Philips Consumer Electronics Co., and Tandy Corp. will cost between $799 and $1,000. Philips, under its Marantz label, will also offer the $1,199 DD-92 and the $1,099 DD-82, claimed to be the only DCC hardware capable of achieving a 105-decibel range through 18-bit analog-to-digital converters. Portable DCC models will appear shortly after the home machines are introduced.

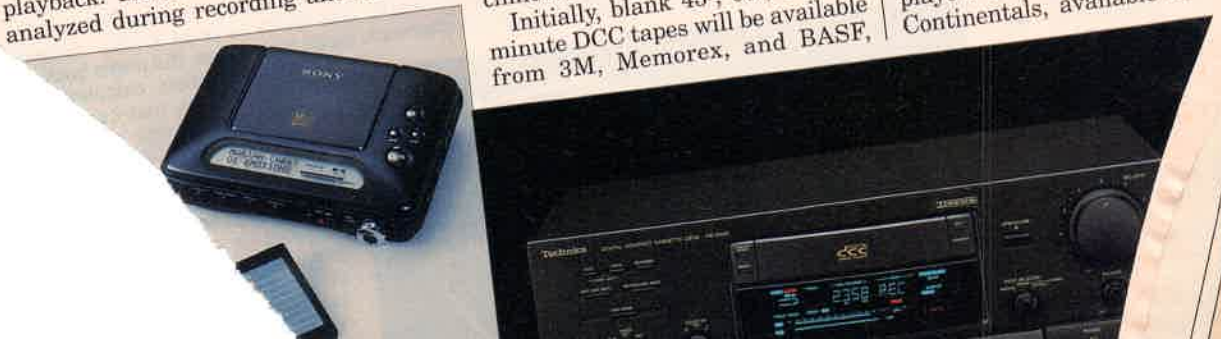
Initially, blank 45-, 60-, and 90-minute DCC tapes will be available from 3M, Memorex, and BASF, with a 90-minute DCC tape costing about $10. BASF plans to market longer-length tapes by 1993. Different grades of tape, similar to those available for analog cassettes, will not be sold at first.

Sony and Denon will market $620 portable MD units by year's end, while Sanyo Fisher Corp. plans to offer MD recorders next spring. Aiwa, Alpine, and Clarion will also introduce MD machines. MD playback-only personal stereos, car products, and mini-component systems are expected to follow the fall debuts. TDK will supply blank discs, but no prices have been set.

Crucial to the widespread acceptance of either system is the support of major record companies. Philips plans to have 500 DCC titles available with the initial introductions of the home machines. DCC proponents have won the endorsement of major recording companies, including Polygram and MCA Records.

Sony claims that it will also have 500 albums available when MD recorders appear. Three major recor companies—Sony's own music lab Warner Music, and EMI Music—and four specialty labels have endorse MD technology.

Car companies are also getting on the act: Ford Motor Corp. wil troduce the first in-dashboard players as an option on 1995 Continentals, available in th



1994. But the car maker isn't taking sides: Ford is also considering an MD changer option for installations where CD changers are too large. Company officials see a time when both MD and DCC products will be available in the same car.—*Marcelle M. Soviero*

Polymer current limiters

Plastics engineered to perform like metallic semiconductors can operate up to 200 times faster than conventional circuit breakers. That can help give costly electrical machinery and electronic gear instant fail-safe protection against short-circuit damage.

Today's electromagnetic breakers interrupt excessive currents when contacts open at mechanical speeds. Also, the contacts create an arc that may lengthen the operating time to half a second or more. Such delays can be very destructive.

Now ABB Control of Vasteras, Sweden, has developed a speedy, solid-state current limiter with no moving parts. The limiter is wired in series with a standard circuit breaker, which then "sees" greatly reduced current when a fault occurs. That minimizes wear and the need for maintenance. The new limiter material is based on a polymer containing electrically conductive particles ["The Strangest Plastics," June '90]. Normally it carries the full load in a circuit with only moderate heating.

A rise in temperature above a preset safe current changes the structure of the polymer's outer layer. This makes the particles separate and increases the electrical resistance. At the critical melting point of about 248°F, the resistance rises 30 times in only 100 microseconds.

The limiter uses the combined action of the temperature-dependent resistance and the "coating effect," which involves only a very thin polymer layer, leaving the material intact. After cooling, the crystalline structure is restored to its original state, and the resistance returns to its original level. The current limiter will appear this year built into complete systems, such as low-voltage switching equipment.—*David Scott*

Do-it-yourself multimedia

Multimedia is the computer industry's buzzword for various combinations of hardware and software that yield high-quality sound and images from a PC. But few computer users have the time or skill to work the sophisticated multimedia "authoring" systems that are normally needed to create a splashy on-screen presentation or a self-running demonstration on their machines.

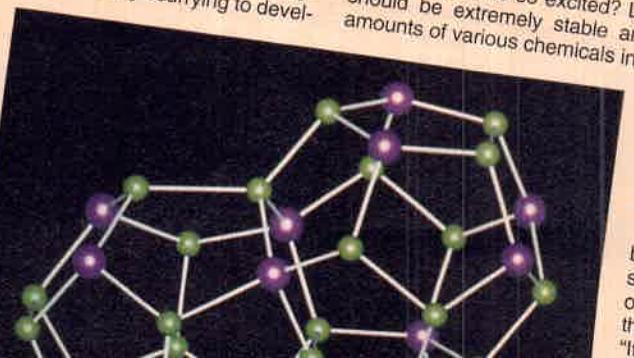
An innovative program called Action from MacroMind, Inc. of San Francisco, however, could change a lot of minds. The $495 Action software uses more than 100 pre-designed templates and a library of graphics, animation, and sound sequences. These help you create scenes incorporating such things as text that slides across the screen, pictures that dissolve from view, and musical accompaniment drawn from a CD audio player.

A more extensive collection of graphics, animation, digitized video, sound effects, and music for use with Action is available from MacroMind on a CD-ROM disk called ClipMedia. All of these elements are manipulated through VCR-like on-screen controls, so you can play, rewind, and fast-forward through scenes as you create them for multimedia sequences.

Action has its limitations, though. You can't do complex animation, and you need a copy of the full software to view whatever is produced with it. Action also has fairly stiff requirements, including the use of Microsoft's Windows interface and a 386- or 486-based PC with four megabytes of memory (plus a CD-ROM player and digital audio card to achieve certain effects). Nonetheless, this may be the first multimedia tool for which the phrase "no

STORAGE MOLECULES

Two years ago chemists at Rice University in Houston discovered a unique soccer-ball-shaped carbon molecule called the "buckyball," which sent researchers across the country scurrying to develop previously undreamed-of applications ["Buckyball: The Magic Molecule," Aug. '91]. Now researchers at Pennsylvania State University have stumbled upon a second class of ball-shaped molecules that could someday have uses in data-storage devices, high-speed computers, or even pollution control.



The scientists believe that the new molecules, which they call metallo-carbohedrenes, or met-cars, consist of carbon atoms linked with atoms of one several metals. They should be extremely stable and could be used to trap minute amounts of various chemicals inside their cages. But unlike buckyballs, theoretical calculations show that the met-cars are somewhat magnetic and conduct electricity—properties useful for electronic devices.

Thus, in theory, they could be used for data storage and hundreds or hundreds than any "It's like

Microwave signals emitted from a vehicle's front-grille antenna (above) provide warnings of impending collisions on a dashboard display (top).

perience necessary" is legitimate. you've got the time and inclina- work a little harder to develop een presentation, another ws program called Anima- nteractive from Gold Disk , Ontario, may be more e $495 Animation et down to the nitty —moving "sprites," path within a ne frame to the es this path and con- ides a can au-

Technic's RS-DC10 Digital Compact Cassette recorder for the home (right) and Sony's portable Mini Disc machine (above) are new-format hi-fi recorders. Mini Discs use an erasable magneto-optical technique for capturing digital data, while the new tape decks use multiple parallel tracks.

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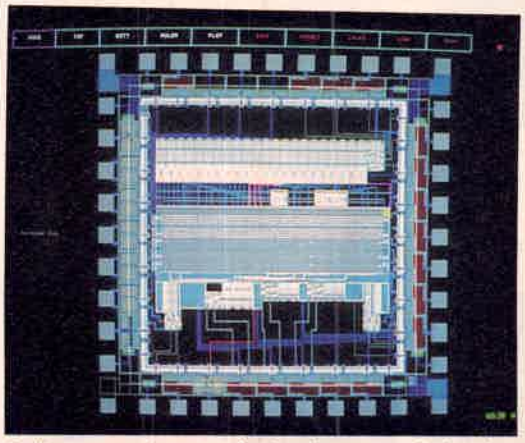
board radar), the system developed by IVHS Technologies of San Diego uses a radar antenna mounted in a vehicle's front grille to sense obstacles ahead. Sophisticated software in a signal-processing module discriminates relatively benign objects, such as a bird in flight, from those that pose a likely threat. When a hazard is identified, the system immediately warns the driver to slow down, stop, or possibly swerve to avoid a collision.



A silicon neuron that mimics biological neurons is displayed as a circuit pattern on a computer screen.

Whether such an alert system makes an impact on road safety should be demonstrated within a few years by Greyhound Lines. The bus company is equipping its 2,400-vehicle fleet with VORAD systems that use a narrow "pencil-beam" radar to monitor objects as far as 450 feet down the road. The version Greyhound is using has a second wide-beam radar antenna that warns the driver of objects in the blind spot on the right side of the bus.

The $5 million worth of equipment Greyhound is purchasing includes a short-term event recorder—much like an airplane flight recorder—that stores data on the most recent 15 minutes of driving. Information on vehicle speed, closing rate with target objects, time of brake application, and steering movements is collected. It can later be retrieved to teach and monitor driver skills or to reconstruct events leading up to an accident, according to Paul Bouchard, president of VORAD Safety Systems.

Scaling down VORAD in size for widespread use in cars depends on the microwave frequency band assigned by the Federal Communications Commission for such use. The bus system uses a flat six-by-eight-inch phased-array antenna to operate on the 24.125-gigahertz band, which is also shared by radar detectors. VORAD triggers some false alarms on the detectors, although initial tests show that it doesn't excite the VG-2 "radar-detector detectors" used by police in Canada and in states that ban use of radar-sensing devices, Bouchard says.

Antenna size could be reduced (and radar detector interference eliminated) if the higher-frequency 60- or 77-gigahertz bands proposed for anti-collision radar in Japan and Europe are adopted here too. Then the antenna would only need to be one-third as large, Bouchard says, although the cost of the electronic circuitry would be higher. He estimates that volume-manufactured systems for cars would cost $500 to $750.

Traffic and obstacle information sensed by VORAD can be used to do much more than trigger bells and whistles. IVHS provided a test drive in a Lincoln car equipped with "adaptive" cruise control, which slows the vehicle to maintain a safe distance from slower-moving traffic ahead. The car also has a system that automatically applies the brakes when VORAD determines that a collision is imminent. This feature could someday be part of a system that would enable automated vehicle "platooning," or convoy-style group driving in close proximity on highways.—*Stuart F. Brown*

Silicon neurons

Researchers have developed a silicon "neuron" that mimics the electrical behavior of biological nerve cells in brains more accurately than other simulation techniques. The devices were formed on silicon chips by Misha Mahowald at the California Institute of Technology in Pasadena and Rodney Douglas at the University of Oxford in England. The performance of the solid-state neurons is so close to their biological counterparts that experts have had trouble distinguishing between the electrical patterns generated by the two.

"Using silicon, we modeled the neuron parts that we think influence its electrical activity," says Mahowald. One of the first-generation devices is about 0.1 square millimeter; about 200 of them would fit on a one-square-centimeter microchip. The silicon neurons, a step toward creating complete artificial nervous systems, operate with analog voltages. *In contrast, other attempts at simulating*

neural activity use standard computer processors, software, and on-off digital logic gates ["Brain-Style Computers," Feb. '89].

In biological neurons, channels or pores within cell membranes regulate electrical impulses by opening or closing, allowing ions to pass in and out of cells. The silicon neurons use electron flow through transistors to emulate these channels and mimic the electrical behavior of cells.

Mahowald and Douglas see big advantages in using very large scale integrated (VLSI) technology for their neuronlike microcircuits. While some attempts at simulating neurons have relied on separate electronic components, VLSI will enable the researchers to put large numbers of high-quality, low-power neural circuits on tiny chips.

Although the silicon neurons might operate about one million times faster than biological cells, the researchers say it's more important to keep the speeds between the two evenly matched. That's because the silicon devices will go into machines designed to perform like real nervous systems. Mahowald and Douglas plan to link chips and create large circuits that model brain functions.

Several universities and hospitals have expressed interest in using the chips for teaching and demonstrations. The Office of Naval Research would use them for advanced sonar or missile-tracking systems. Another potential application would be for robots that perform tasks on their own.—*M. M. S.*

National caller ID?

Few issues have pitted technology and privacy more squarely against each other than the debate over caller ID, the telephone company service that lets you see the phone number (and in some cases, the name) of the person who's calling before you pick up the receiver ["Look Who's Calling," July '90]. Some states allow caller ID, some outlaw it, and many are still in the process of deciding. But the Federal Communications Commission (FCC) may soon give the service a boost with the adoption of a national caller ID policy.

The proposed FCC policy would permit the use of caller ID but mandate free "per-call blocking," meaning a caller could block the transmission of his phone number or name when making a call by simply entering a special code (such as *67) before dialing the regular number. The per-call blocking option, which already is being offered in Illinois, Florida, and several other states that have approved caller ID, is a compromise of sorts. Many of the regional Bell companies and independent operators would like to offer caller ID with no blocking restrictions, as Bell Atlantic does in New Jersey and West Virginia, for example. Some consumer advocates, on the other hand, would prefer "per-line blocking," which would allow customers to pay a one-time fee for opting out of the caller ID system.

"We're trying to strike a balance between the privacy rights at both ends of the line, and, at the same time, not destroy what we believe to be a very useful service," says Jim Spurlock, special assistant to the chief of the Common Carrier Bureau at the FCC, the department that handles telecommunication issues.

The FCC's ruling on caller ID, expected this summer, would establish a federal model for state regulations regarding the controversial service. It's

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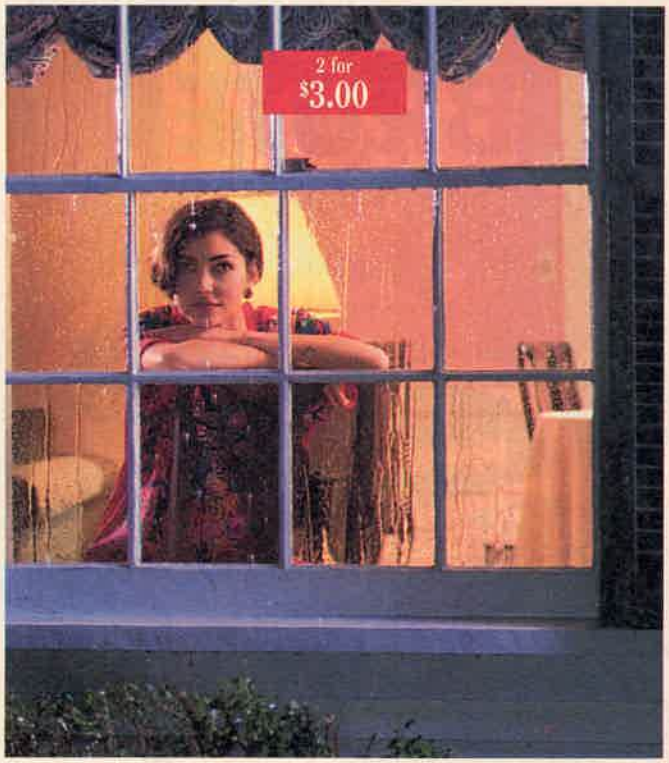

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not clear whether the FCC standard would legally require each state to conform to the national policy, since the FCC normally presides over interstate issues only, not matters within a single state.

But if the FCC finds that caller ID is an "inherent mix" of statewide and interstate issues, says Spurlock, it could negate state regulations that forbid or heavily restrict the service. Many industry observers believe the FCC will do just that, as it did when Georgia attempted to prohibit a regional phone company from offering an answering service known as Memory Call. The courts have tended to side with federal regulators in such disputes.

Of course, adding the contentious issue of states rights to the often acrimonious debate over privacy is not likely to quiet the quarreling anytime soon. By one measure, at least, there is still time for debate: It will be several years before every part of the country has access to Signaling System 7, the all-digital switching network that makes services like caller ID feasible. "It's definitely not over yet," says Gene DeRose, director of research at Jupiter Communications, a New York newsletter publisher.—*C. O.*

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Write of passage

High school seniors know that applying to college can be a time-consuming and frustrating rite of passage, filled with unending forms and the same essay question phrased innumerable ways. Now a software service plans to make that process faster, easier, and more efficient.

The company, Enrollment Collaborative of Concord, Mass., coordinates and computerizes the flurry of paperwork between the student, the high school, and the college. Students who subscribe to CollegeLink software complete *one* application on a personal computer, which the company then formats to each institution's preference. Students can send this application to as many as a dozen schools that they select from more than 200 colleges and universities participating in the service.

Meanwhile, high school guidance counselors can send transcripts to CollegeLink, which scans and merges the files with each student's application. Colleges then receive the complete application package on both paper and disk. Copies of these forms are sent back to the high school for record-keeping and to the student, who can verify all of the information and sign the forms.

Students can subscribe to CollegeLink for $30, plus shipping fees. The software is available in both Macintosh and IBM (or compatible) versions. The company offers free subscriptions to high schools, and this year there is no fee charged to participating colleges.—*Judith Anne Yeaple*

Electronic panning

Slide your finger over a video screen at a Bellcore site in Piscataway, N.J., and images on the monitor shift left or right, tracking your hand. At first, the demonstration seems to be simply a touch-sensitive monitor controlling the horizontal panning of a nearby TV camera. But when another person touches a second monitor attached to the camera, images on that screen begin panning left while pictures of the demonstration room on your monitor still pan to the right.

What's happening? The main clue: Bellcore's cigar-box-size TV camera

between the two monitors isn't shifting left or right—it's stationary. Researchers for the regional Bell operating companies wouldn't disclose details about their experimental all-electronic panning-camera system because patents are still pending.

A new computer concealed beneath the camera table at the New Jersey demonstration has a key role, however. Images from a number of charge-coupled devices (CCDs) within the camera, which are similar to the light sensors in ordinary camcorders, are electronically "stitched" together, creating a broadband video signal. The camera lens and CCDs provide a wide field of view (about 60 degrees) that can be electronically "sampled" by an unlimited number of viewers, each obtaining their own narrower view. Bellcore researchers say they're working on a camera system with a 360-degree field of view.

Here's how a system might work if others license this new technology: Broadband signals from wide-angle cameras would be sent to a central point—perhaps a telephone switching center or a cable-TV head end. Subscribers, using remote controls and small receivers also equipped with a special microcomputer, would tap a portion of the broadband signals.

A 180-degree view broadcast from a football game, for example, would enable home viewers to select the action that interests them. For group teleconferencing, participants could pan back and forth independently. The researchers say security is also a good application and demonstrated how simple movement such as waving a hand makes the camera system pan toward the motion. Wide-view cameras could also be set up at roadway junctions. Before making a trip you could dial different numbers and view traffic conditions.

Electronics notes

- An ultracompact hard-disk drive that stores more than 21 megabytes of data has been introduced by Hewlett-Packard Co. The tiny device weighs about one ounce and measures 0.4 inch by 2 inches by 1.44 inches. The hard disk is 1.3 inches in diameter.
- Although most Japanese firms are aiming at liquid-crystal technology for future flat-screen hang-on-the-wall TVs, the country's public broadcasting service, NHK, is refining flat gas-plasma color displays with help from several firms ["Flat TV," Jan.]. In June, NHK researchers revealed a 40-inch-diagonal, three-inch-thick prototype. An improved version of the plasma panel may be sold by 1997.
- Researchers from AT&T Bell Laboratories and Japan's Kokusai Denshin Denwa Co. linked two 2,790-mile-long optical-fiber systems at a New Jersey lab. Instead of conventional repeaters, the system used optical amplifiers, which boost the signal capacity of undersea fiber cables 7.5 times, to 600,000 two-way phone conversations ["Best of What's New," Dec. '91].
- A light-valve video-projection system developed by Hughes Aircraft Co. for military and industrial displays is inching toward home use ["Wall-Size TV from Tiny LCDs," June '91]. Hughes has joined with JVC to develop a consumer version of its very bright, giant-screen projectors. Images are much brighter than conventional video projectors because high-intensity lamps reflect powerful beams from mirrors built into light valves. The new company, Hughes JVC Technologies, is in Carlsbad, Calif. PS

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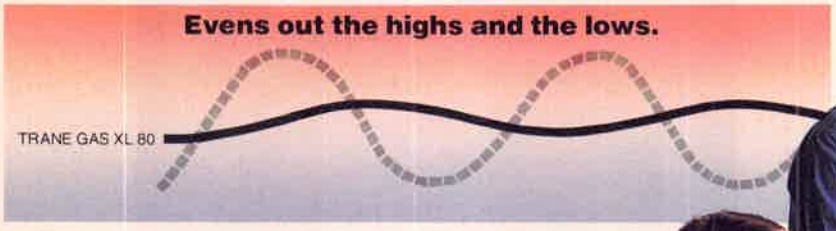

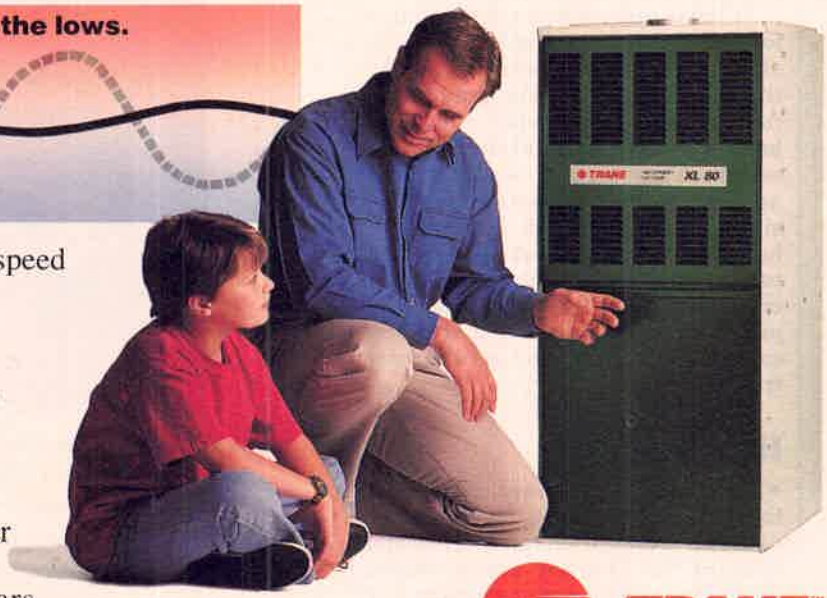

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Home Newsfront

Edited by MARIETTE DiCHRISTINA

House of plastic

In one of the most northerly, coldest, and—for four months of the year—darkest countries in the world sits a plastic solar-powered show house with a mission: to challenge conventional wisdom.

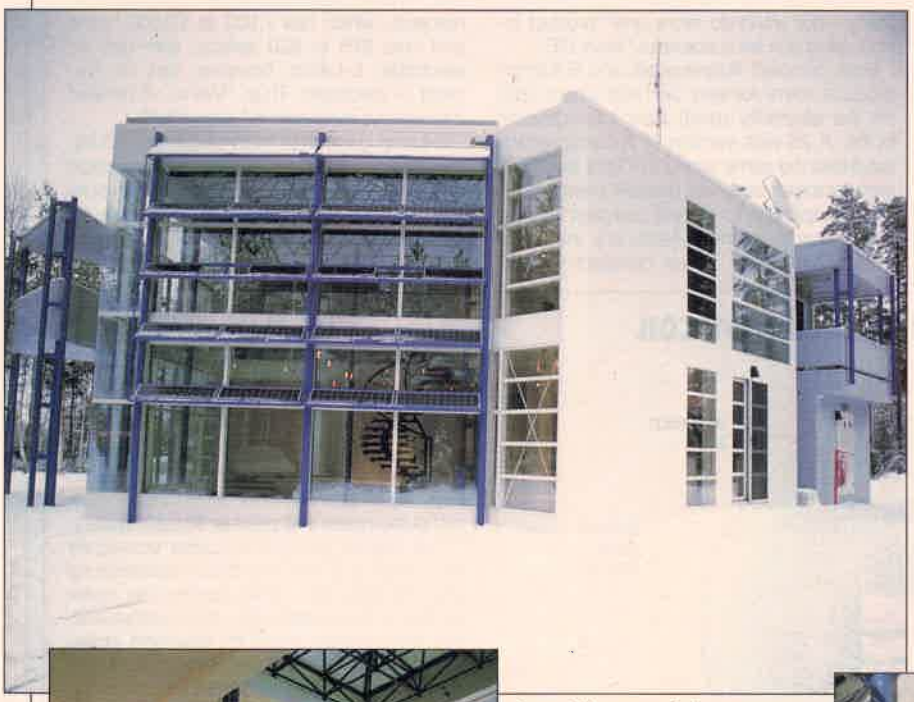
The 2,700-square-foot Nestehaus in Porvoo, Finland, was built in a $2.3 million project by Neste Chemicals, a Finnish manufacturer of plastics. The structure of Nestehaus is 75 percent plastic, and the house is powered by a cost-efficient energy-saving solar power system. The company's intention is to boost plastic's image as an alternative to conventional building materials.

Modular recyclable plastic forms are used throughout the house. Designed by Neste's U.S. subsidiary, Excel, a series of screw-fit plastic blocks make up Nestehaus's tubular pillar elements; steel-reinforced concrete bolstered with polypropylene fibers is packed inside the load-bearing members. In the window frames and supporting pillars, fiber-reinforced polyester resins are used.

The house's fire-resistant plastics won't discharge toxic fumes if burned, according to Neste. The bathroom and garden tiles are made with waste plastics—recycled leftovers from Neste's production of polyvinyl chloride, polyethylene, and polystyrene plastics.

The photovoltaic system was designed in collaboration with the International Energy Agency and is commercially available in Finland. The system produces direct current electricity that is inverted to alternating current for household use. Nestehaus's solar-energy system consists of 24 photovoltaic modules, a battery storage unit, and an electronic control element. The modules are of three different types: conventional single-crystal silicon by Arco, amorphous silicon by NAPS (Neste Advanced Photocellular System) France Ltd., a Neste research facility, and near-transparent Sanyo amorphous modules, which are used on some of the windows.

The system's peak output is 950 milliwatts, with an annual production of 650 kilowatt-hours. It produces 20 to 30 percent more electricity than is needed to run the house; the excess is fed into the grid. Because of its triple-glazed windows, insulation, and energy-efficient design, Nestehaus requires 30 percent less energy than a conventional house, according to Neste.
—Wordservice International



Some 75 percent of the structure of the demonstration Nestehaus (above) in Finland is made of plastics. For example, the staircase (left) is entirely plastic. In conventional construction, plastics account for just 5 percent of materials.

Conventional solar panels (above) provide the energy-conserving Nestehaus with more power than it needs; the excess goes out to the grid.

NEXT WAVE OF EFFICIENT LIGHTING?

BY MARIETTE DiCHRISTINA

A century ago, Nikola Tesla experimented with high-frequency induction coils to produce light. Now long-lasting energy-conserving induction, or electrodeless, light bulbs are achieving commercial reality to hosannas from the media and others. Is the new bulb the energy-efficient heir apparent to incandescent—and fluorescent—home lighting?

"This is the lighting of the future," declares Jim Pfeiffer of Diablo Research Corp. in Sunnyvale, Calif. Diablo developed a patented 20,000-hour electrodeless bulb called E-Lamp with Intersource Technologies of Sunnyvale and American Electric Power Co., an electric utility in Columbus, Ohio. E-Lamp, which will be introduced in versions for homes and businesses next year, will match the efficiency of the best compact fluorescents on the market. The price for E-Lamp is expected to be near the cost of compact fluorescents, around $20.

There are other electrodeless efforts under way. Since May 1991, Philips Lighting Co. has been selling the QL Induction Lighting System to European businesses ["Best of What's New," Dec. '91; "Home Newsfront," Oct. '91]; Philips anticipates a U.S. introduction next year. The company isn't currently planning a bulb for households. GE Lighting of Cleveland has long researched electrodeless technology—it recently demonstrated a version at the Hanover Fair in Germany—but won't do more until "product introduction can be successful," says GE.

Both compact fluorescents and E-Lamps produce more lumens per watt (more light for the electricity used) than incandescent bulbs. A 25-watt version of E-Lamp, which produces the same amount of light as a 100-watt incandescent, will provide energy savings comparable to current compact fluorescents made by manufacturers including Philips and GTE. These compact fluorescents can use, for example, 18 watts to create the amount of light generated by a 75-watt incandescent.

The difference: "Our bulb lasts longer," says Pfeiffer. E-Lamps will have twice the life of compact fluorescents and up to 30 times that of incandescent bulbs.

In conventional light bulbs, which work for 750 to 1,000 hours and cost about 75 cents, electricity passing through a tungsten filament creates incandescence. Compact fluorescents, which last 7,000 to 10,000 hours and cost $15 to $20 apiece, also use an electrode. E-Lamp, however, has no filament or electrode. Thus, "We've eliminated the burnout mechanism," says Pfeiffer.

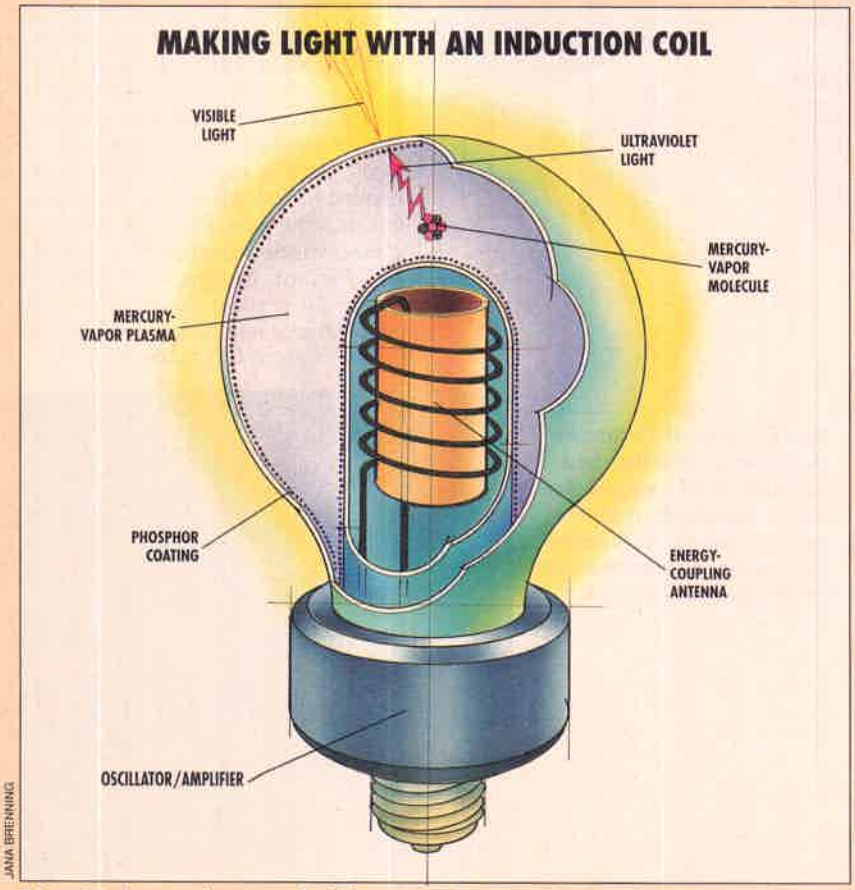
E-Lamp generates high-frequency, 13.56-megahertz radio waves with an induction coil. The energy flow excites a low-pressure mercury gas vapor—essentially the same as in conventional fluorescent lamps—inside the bulb, creating a plasma. "Once you have generated the mercury-vapor plasma, the process is the same" as in fluorescents, says Pfeiffer. These mercury vapor gas molecules give off ultraviolet radiation, which in turn excites the glass bulb's phosphor-powder inner coating to produce visible light.

The electrodeless bulb dims as the phosphor ages. At 20,000 hours, E-Lamp phosphors are degraded by 30 percent. (Philips says the phosphors in its commercial/industrial bulbs reach that point at 60,000 hours.)

The higher cost of E-Lamp would be recouped in a few months in commercial and industrial use, where lighting can make up half of the electric bills, says Intersource. But the savings aren't as dramatic in the home, where lamps account for some 6 percent of energy use, says the Edison Electric Institute in Washington, D.C. In homes, E-Lamp would pay back its price in energy savings after three years if used for four hours a day. The bulb would last for 14 years at that rate.

E-Lamp will have the familiar shape of an incandescent (as does the Philips bulb), and it will be smaller than many compact fluorescents. Unlike the Philips bulb, which requires a dedicated fixture, E-Lamp's electronics are located in the bulb's base, which will screw into a conventional socket.

If Intersource can deliver the $20 price, E-Lamps would be a better deal than compact fluorescents for households where lighting is needed at least several hours a day. But if you have the fixture, a four-foot fluorescent tube seems more attractive. The tubes can cost just $1 to $5. They are as energy-efficient as compact fluorescents and E-Lamps. And they can last 20,000 hours—the same as E-Lamp. PS



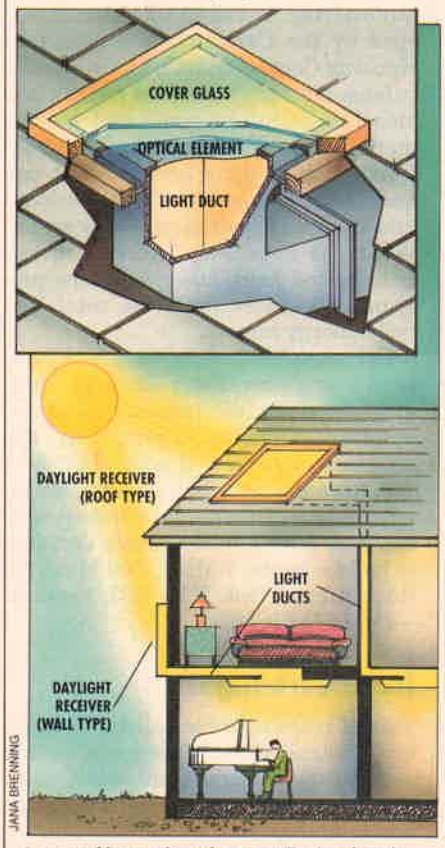
E-Lamp's induction coil generates high-frequency radio waves that excite mercury vapor molecules. These give off ultraviolet radiation, which makes the phosphor coating produce visible light.

Piped-in sunlight

Sanyo Electric Co. of Japan is developing a solar duct that will bring natural sunlight deep within a building. It will be less expensive and more reliable than more complicated schemes that use sun-tracking mechanisms, mirrors, and fiber-optic cables, claims the company.

A daylight receiver mounted on the outside of a building or house aims sunlight down a highly reflective duct that can convey the light even through a few 90-degree turns (see illustration). Sanyo researcher Norioki Fujimoto says the efficiency of the system depends on minimizing the number of times light rays reflect off the sides of the duct. "At each reflection, we lose light energy because of scattering," he adds.

Within the daylight receiver is a two-layer Fresnel lens. The lens refracts, or bends, light rays no matter what the incident angle, so the emerging rays are nearly parallel to the axis of the duct.



Low-profile panels and a specially developed Fresnel-type lens collect sunlight and disperse it through a house in a Japanese solar duct system.

Fujimoto says that even on partly cloudy days, an 11-square-foot receiver and duct—even if it has a few turns in it—can illuminate a 110-square-foot room with 50 footcandles of light—more than enough for reading. One drawback is the building space lost to the ducts. Sanyo says, however, that the ducts could do double-duty if they were fitted with solar-powered fans to help ventilation. The company is also considering alternatives for the duct-lining material; currently they're lined with aluminum, polished to a mirror finish.

Fujimoto says commercialization is at least a year away. "We are trying to optimize the prism," he explains. Sanyo hasn't yet decided whether it will market the system outside Japan. *—Dennis Normile*

Home, environmental home

To most people, an energy-efficient home is one that goes easy on the gas, oil, and electric bills. With a tight building shell and energy-conserving lights and appliances, you've got an efficient house, right? Not quite.

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LAWNS OF THE FUTURE

Slow-growing, water-conserving strains of crested wheatgrass (above), originally from Iran and Turkey, may help provide U.S. homeowners with lower-maintenance lawns.

Drought tolerant. Self-feeding. Lower maintenance. These are some of the attributes of landscaping in the near future as envisioned by scientists at the USDA Agricultural Research Service. The researchers are working to adapt plants that are native to other countries and climates to American needs.

Strains of the crested wheatgrass *Agropyron cristatum* originally from Iran and Turkey, for example, may be ready for commercial use within five years. "They need only about a third of the water required by most lawns," says Kay H. Asay, a USDA plant geneticist in Logan, Utah. "And because they grow more slowly, the lawns won't need to be mowed as often." The grasses also resist common lawn pests, such as sod webworms and billbugs.

The gene pools of the Alaskan star moss, or *Tortula ruralis*, may also provide a key to less-thirsty lawns. With a few drops of water, the moss can transform itself from a brown, dried-out tangle to a rich green mass. Seen through an electron microscope, the brown moss can show 90 percent cell damage before it's watered. "Yet it somehow repairs most of this damage minutes later," says Mel Oliver, a USDA plant molecular biologist in Lubbock, Texas. Oliver is using copies of the moss genes to search for the repairing genes; transferred to other plants, these genes could make the plants drought tolerant.

Lastly, after a recent two-year study, researchers confirmed that a tree native to Manchuria, *Maackia amurensis*, can feed itself. The tree, which already grows in some areas in the United States, forms tiny nodules on its roots that become homes to nitrogen-fixing rhizobia bacteria. As a result, the trees don't need nitrogen fertilizer, saving costs and lowering the chance of nitrate pollution of nearby water sources.

A problem that still remains: finding a practical way to inoculate the soil around seedling roots with the special bacteria, says the USDA's Peter B. van Berkum in Beltsville, Md. "Once we have fine-tuned these procedures, the tree could be available for retail sale within the next several years," he adds.—*M. D.*

JOHN B. CARNETT

With a small amount of water, dried Alaskan moss with 90 percent cell damage rejuvenates in minutes. The moss genes may help make sturdier, drought-tolerant yards.

Having dramatically cut energy use in new homes over the past 20 years, builders and researchers are now seeking to reduce the total life-cycle energy-use impact of homes. That is, not only the energy consumed by occupants in a house—called operating energy—but also that used in harvesting, manufacturing, transporting, and installing the house's materials and systems—the embodied, or capital, energy.

Energy use and environmental impact can vary significantly depending on design and selection of materials. A choice that looks good on one ledger may be poor on another. Rigid foam insulation made with chlorofluorocarbons or hydrochlorofluorocarbons, for instance, contains heat well, but the manufacturing process destroys upper atmospheric ozone.

A new software program called Optimize can help with the difficult job of quantifying these tradeoffs. Developed by the Canadian Mortgage and Housing Corp. (CMHC), Optimize calculates not only embodied energy, but also the pollution generated by the manufacture of different building materials and designs and by their use and maintenance—their operational and embodied pollution, so to speak. When the house's operational energy is imported from other software programs, Optimize finds the total life-cycle energy impact.

For now, according to CMHC research engineer Peter Russell, Optimize is on limited release, mainly to other researchers. Nevertheless, the program represents a significant first step toward untangling the complex interplay of environmental effects resulting from a once fairly simple decision: to build a house. CMHC, 700 Montreal Rd., Ottawa, Ont. K1A 0P7, Canada. —*David Dobbs*

Trash exchange

Tons of building materials left over after construction or ripped out during renovation become trash each year, wasting usable raw and finished goods and jamming crowded landfills. But at the new 15,000-square-foot ReUze Building Centre near Toronto, builders and buyers can recycle lumber, drywall, cabinets, doors, windows, and even plumbing and electrical fixtures.

"It's like a Goodwill store for used building materials," says co-owner Ron Sawatsky.

Builders and the general public drop off sorted items, saving tipping and hauling fees. Do-it-yourselfers and construction professionals can then buy these goods at no more than 50

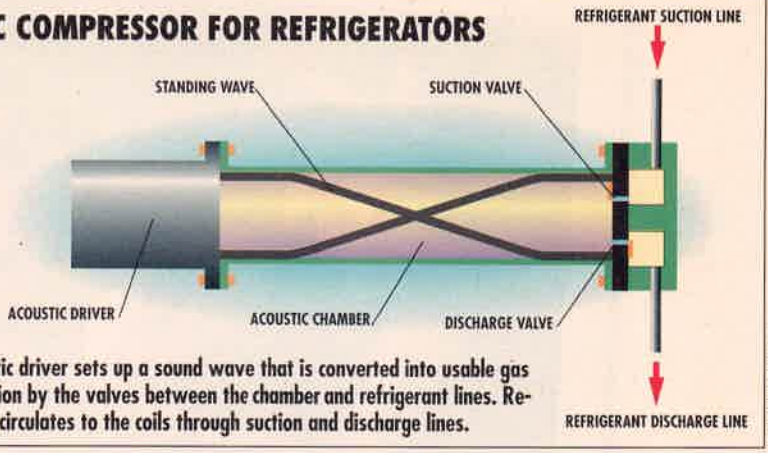
percent of retail prices. ReUze Building Centre, 380 Birchmount Rd., Unit 3 Scarborough, Ont., Canada M1K 1M6.—*P. J. Skerrett*

A sound idea

Home refrigerators currently account for roughly 8 percent of all electricity consumed in this country, and they rely on ozone-depleting chlorofluorocarbons (CFCs) for cooling. Congress has mandated that 1993 refrigerators must be 30 percent more efficient than 1990 models. In addition, the United States is committed to a 50 percent decrease in CFC use by 1995, with complete elimination by the year 2000.

A new type of refrigerator compressor that uses resonant sound waves will provide energy savings of up to 40 percent and be easily adaptable to new non-CFC refrigerant systems. Developed at Los Alamos National Laboratory in New Mexico by physicist Tim Lucas, who invented it, and Greg Swift, a consultant, the sonic compressor will require no retooling by manufacturers and could be standard equipment in new refrigerators in two or three years. Eventually, it could also be designed for installation in existing refrigerators.

SONIC COMPRESSOR FOR REFRIGERATORS

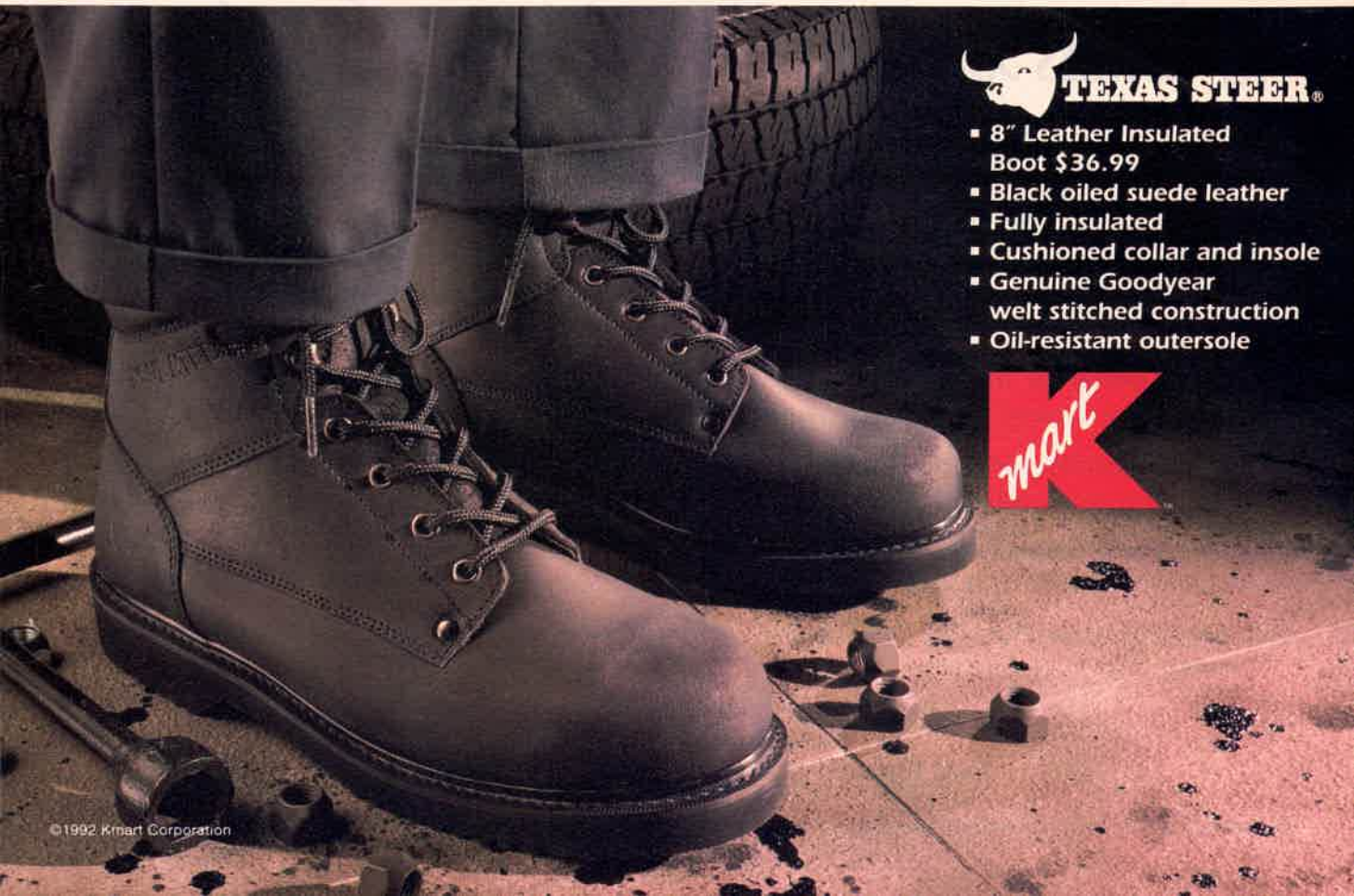


An acoustic driver sets up a sound wave that is converted into usable gas compression by the valves between the chamber and refrigerant lines. Refrigerant circulates to the coils through suction and discharge lines.

JOSEPH ULATOWSKI

In a conventional compressor, the heart of any refrigerator, an oil-lubricated piston-and-cylinder device mechanically compresses refrigerant gas to produce cooling. In the new compressor, an acoustic driver, which functions somewhat like a bass loudspeaker, uses electrical power to set up resonant sound waves with pressure amplitudes up to 100 pounds per square inch. The sound waves then compress the refrigerant when they pass through a pair of high speed, 340-cycles-per-second, one-way valves. Lucas has formed Sonic Compressor Systems of Richmond, Va., to commercialize the new device.

Thermoacoustics, another sound-cooling technology, from the Naval Postgraduate School in Monterey, Calif., is also moving ahead ["Best of What's New," Dec. '91; "Home Newsfront," July '91]. Cool Sound Industries in Port St. Lucie, Fla., has exclusive license for the thermoacoustic air-conditioning, and General Electric is building home refrigerators in Monterey. The technology could be commercially available in three years. —*Ray Nelson* PS



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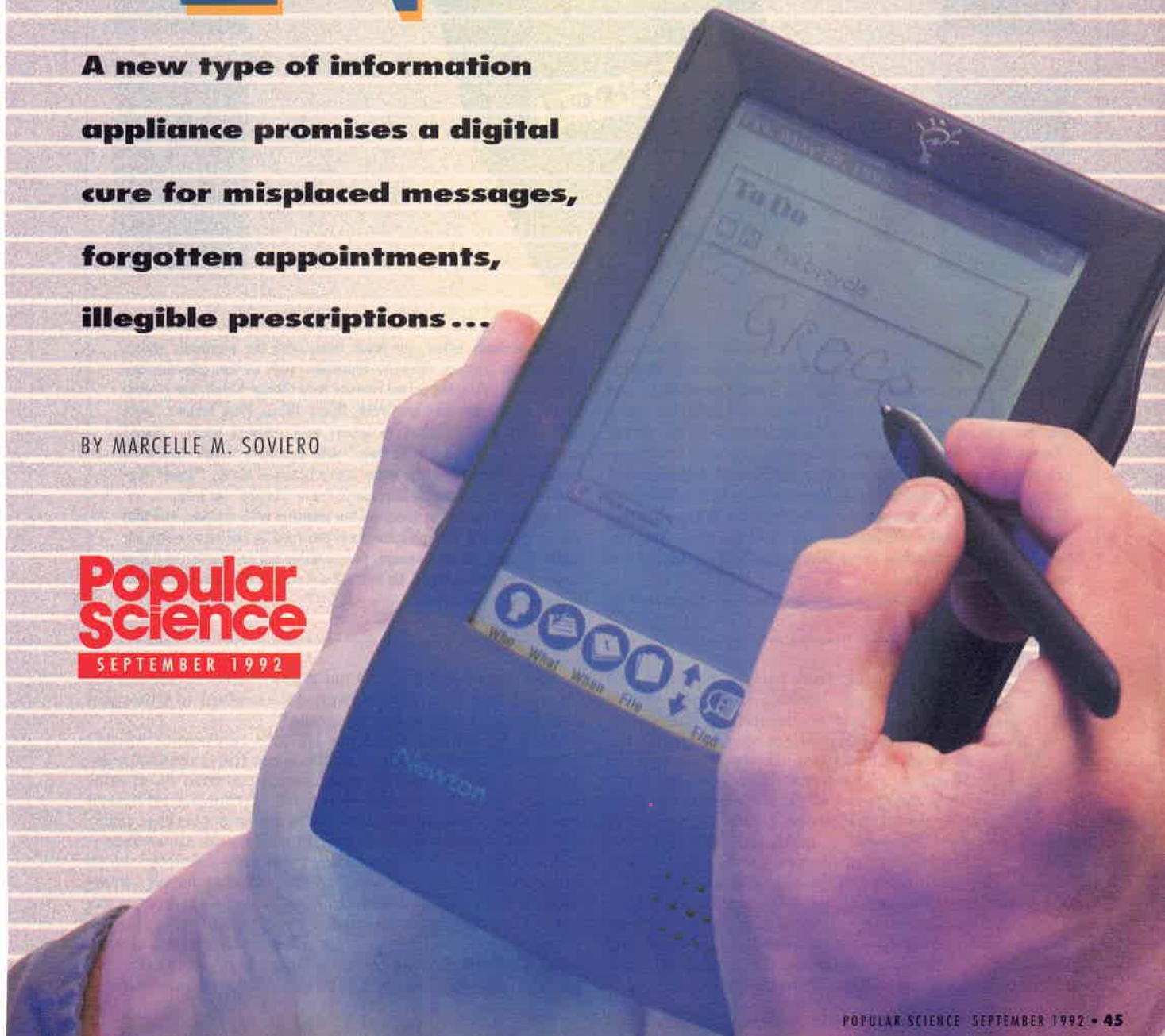
Buckle Up, America! GM

Your world according to Newton

A new type of information appliance promises a digital cure for misplaced messages, forgotten appointments, illegible prescriptions...

BY MARCELLE M. SOVIERO

Popular Science
SEPTEMBER 1992



NEWTON: THE INFORMATION TASKMASTER

Newton's intelligent software makes the device more akin to an assistant than an electronic organizer or a personal computer. Newton learns key phrases such as "fax this," or "remind me of that," and makes simple assumptions to assist you with such tasks. For example, say you jot down a letter to Larry, followed by the phrase "format this." Newton will select a business form letter from memory and automatically format the letter with Larry's address pulled from your electronic address book. Now you want to fax the letter? Hook Newton up to a fax machine write "fax this to Larry" on the screen, and the device will automatically churn out a fax cover letter, fill in the appropriate cover information, pull up Larry's fax number, and send the fax.

Seven icon buttons located along the bottom of the notepad screen issue commands when you touch them with the electronic stylus. Each button triggers different functions, such as the calendar and phone book. While the actual buttons may change before the product is sold, at present they are: Who, What, When, Find, Format, Send, and Assist. Press "Who" to access your address book; "What" opens up your to-do list; "When," your calender; "Find" checks for messages; "Format" turns notes into a business letter; "Send" faxes a letter to a colleague. Confused? Press "Assist" for help.

Touch a certain day or week on the calender with the pen, and that day or week will be highlighted and enlarged to full-screen-size for easier viewing. Draw a square, then scribble out one corner, and that corner is instantly erased. Or write 2 + 4 =, and the answer instantly appears on the screen.

K. DANIEL CLARK

You're thinking that this little black box called Newton doesn't look like much. Well, looks can be deceiving. This seemingly plain-Jane gadget may be the breakthrough information device of the decade: It's only a prototype right now, yet Newton's designers at Apple Computer can't help but gush about plans for an entire family of so-called Personal Digital Assistants (PDAs) that will someday be as ubiquitous as radios and televisions—only far more powerful, interactive, and useful.

At a glitzy unveiling in Chicago earlier this year, John Sculley, Apple's chairman, slipped one from his coat pocket as if uncovering a precious gem. The lights dimmed and a drumroll snapped to a finish as Sculley attempted to define the world according to Newton.

"The big idea is that it's not a tool, it's an assistant," he says. "A tool is a lawn mower. An assistant is when you hire someone else to cut the grass."

As a digital aide-de-camp, Newton represents Apple's boldest technological innovation since the company redefined the idea of the personal computer with its revolutionary Macintosh eight years ago. Wrapping advanced hardware and sophisticated software in a portable package that presumably anyone can use and appreciate—*without* a stack of instruction manuals—Newton is at once the electronic answer to the informationally overheated '90s, and a potential two-way access point for the digital era that looms beyond.

Don't mistake the fledgling PDA with a general-purpose pen-based computer or a super-high-end pocket organizer, although Apple's PDA is obviously a successor to

both. The heart of Newton is its ability to recognize printed handwriting and graphics, organize that information, and communicate it to others. Apple's PDA is remarkably user-friendly—as simple to use as a pen and paper. Instead of jotting down reminders on yellow sticky notes, or writing grocery lists, phone messages, and business appointments elsewhere, Apple's PDA is designed to centralize all of this information and store it in one place.

Everything you write on a PDA screen is stored independently in a collection of data. Newton organizes these seemingly disparate pieces of information—and makes them much more accessible. By storing data in this way, Newton lets you look up, say, everything related to your income taxes or everything that relates to Bob Greene. It can associate "Bob" in your PDA calendar with "Bob" in the machine's address book. Information can also be customized: For instance, if you want to add a space for birthdays in your electronic address book, you can do so just as you would on paper.

Apple's PDA can be upgraded with plug-in "smart" and memory cards. These might convert a PDA notepad into a reference library, a travel navigator, a language translator, a receiver for paging-type messages, or an electronic copy of *War and Peace*, for example. Apple has formed the Personal Interactive Electronics division, or "Apple Pie," to develop PDAs and other gadgets for the digital age of the future.

PDAs will have a built-in facsimile and data modem. Apple has teamed up with SkyTel, which runs a satellite paging network, so that a PDA equipped with a special integrated-circuit (IC) card could receive electronic mail from almost anywhere on the globe.

"Moving information around and sharing ideas is what Newton is all about," says Sculley. "Telecommunications are as important to Newton as graphics were to the initial Mac."

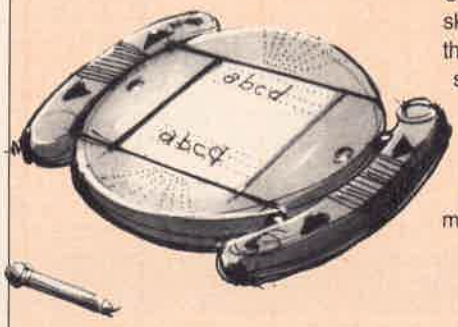
Newton machines can also communicate easily with other data devices either by infrared signals or by outboard fax/modems. The device's electronic "in-box" can contain electronic-mail messages, and the electronic "out-box" can store outgoing information, such as a fax being held until it is sent at a certain time. With the push of a button you can send or receive information to or from other PDAs or Newton-compatible devices. You can unplug and re-plug Newton without destroying a network. Traveling Software, a portable communications software company in Bothell, Wash., is supplying software for Newton that permits data exchanges between PDAs and personal computers.

Hewlett-Packard's palmtop computer, the 95LX, already has blazed the wireless data communications path through a link with Motorola's so-called newstream receiver. Metriplex, a communications company in Cambridge, Mass., has announced a leasing program for a 95LX, the Motorola receiver, and Metriplex's own DataPulse software that enables you to receive and automatically track financial data.

Newton is the inaugural manifestation of a technological concept that Apple has been hinting about since the '80s. Four years ago Sculley introduced Apple's Knowledge Navigator concept in a video produced by *Star Wars* creator George Lucas. The Navigator featured, among other things, a built-in "digital assistant"—represented by a face on the screen—that took notes, gave messages, and answered questions through spoken commands. The best computer never built conducted research in distant databases on its own and displayed full

FOUR FUTURE FACES OF NEWTON

SPELL AND STORE

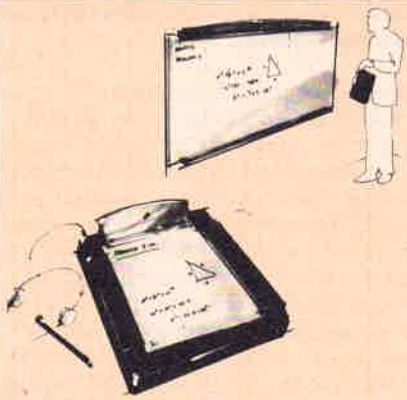


Children could learn to sketch and write while the Newton draw-and-spell corrects spelling along the way. Games, lessons, or a child's drawings could be stored in memory.

LET YOUR FINGERS DO THE TALKING

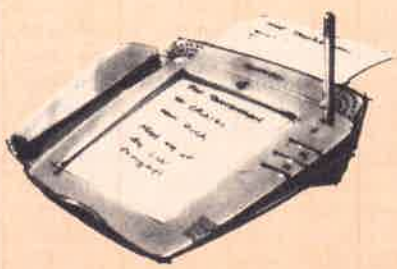
The Newton facsimile/phone could store your entire phone list or print the name and number of a caller immediately. If the person you are talking to has a Newton fax/phone you could share notes, or fax them.

ELECTRONIC MAPS AND MORE



Mating Newton technology with global-positioning satellites could enable you to find your location anywhere in the world. Inserting memory cards for particular regions would let you explore specific streets, restaurants, or museums.

ROOM WITH A VIEW



In classrooms equipped with Newton boards and desks, teachers could save notes or bring up stored lessons on the board, while students view them on their desk screens via wireless networks.

Sharp is introducing its pen-based OZ-9600 (above) in the United States and the more-expensive PV-F1 Action Manager in Japan, a separate pen-input machine that accepts function cards designed for the company's Wizard electronic organizers.

multimedia capabilities and a built-in videophone.

Apple's first PDA model, priced at "less than $1,000," should arrive in stores early next year at a time when emerging electronics technologies promise exciting new options. Digital technology, with its ability to store and retrieve massive amounts of data, offers new opportunities for both accessing information and interacting with other people. The communications industry is rapidly expanding wireless networks and boosting the capacities of wire telephone links. Sculley stresses that widespread digital-communications networks will be as important to creating a new industry of PDAs in the 1990s as the IC was in launching personal computers in the late 1970s. PDAs would enable you to transmit and receive fax messages and serve as data terminals for other text, voice, and even video information such as picture-phone communications.

You will eventually find other choices in stores too. Apple has licensed Newton technology to Sharp Consumer Electronics in Japan. Sharp will offer its own models, in addition to making PDAs for Apple. Apple has also teamed up with Toshiba to produce special PDAs capable of playing CD-ROMs, which add advanced graphics, video, and audio capabilities ["Multimedia," Dec. '91]. Sharp has added a pen as well as other amenities, including a touch-screen and wireless communications to its line of Wizard electronic organizers ["Electronics Newsfront," Jan. '89]. The OZ-9600 will be available late this year or in early 1993 for between $600 and $700. The model can transfer information to a computer or another Wizard without cables or wired connections as long as both machines are within sight of each other. While the OZ-9600 stores anything you write on the screen directly, its sister model, the PV-F1 Action Manager, has character-recognition capabilities that translate crude printing into computer characters. The PV-F1 costs about $1,000 in Japan.

In addition, Tandy Corp. in Fort Worth, Texas, and Casio Computer Co. in Tokyo are jointly developing Personal Information Processors for next year with a target price of about $500. These devices will be similar to PDAs but will have less horsepower and longer battery life, claims Tandy. Casio and Tandy are adapting GeoWork's GEOS, an existing graphical operating system already used in personal computers, to the upcoming lightweight devices. Additional details on this so-called PIP are yet to come.

Richard Shaffer, a veteran industry analyst who has been tracking the new gadgets, believes the differences between Newton machines, other organizers, and pen-input computers lie almost exclusively in the concept behind the product. "A lot of people are sort of throwing hardware out here and seeing what people will buy," he says. "The thing about Newton is it has the same kind of 'gosh-that's-great appeal' that makes shoppers lust after gadgets in Sharper Image catalogs and stores. By making the machine look and feel like a notepad, people will immediately get the idea of it, and that's part of the appeal."

Paul Saffo, a research fellow at the Institute of the Future in Menlo Park, Calif., classifies Apple's PDA as an information appliance. "It's a new product category that combines the information richness we associate with computers with the low cost, convenience, ease of use, and ultra-portability associated with consumer electronics," he says. "Things acceptable in the computing environment are utterly unacceptable in information appliances, such as having to switch applications or remember file names."

This new product category requires a fresh outlook and perhaps should be viewed from its interface, such as a write-on screen, inward, and not as a collection of technologies, which is how the personal computer is viewed. Acceptance of personal computers lies in how software transforms them from general-purpose machines to tools with specific features and capabilities. "The success of these new appliances lies in how the pieces work together," says Saffo.

A significant difference between Newton devices and current electronic organizers or personal computers is that Newton technology uses a 32-bit ARM 610 RISC (reduced-instruction-set-computing) processor. This specially designed chip packs the performance of personal

computers equipped with the most powerful microprocessors. The RISC chip, which consumes the equivalent energy of a small flashlight, enables the Newton machine to perform a number of simple instructions, such as those needed to quickly recognize your printing ["Next-Generation PCs," April]. RISC chips are currently used in high-speed workstations for scientific and engineering applications. Four AAA batteries are expected to power the Newton-based notepad for an estimated eight hours.

To expand its functions, Apple's one-pound notepad has a PCMCIA (Personal Computer Memory Card International Association) 2.0 card slot for memory and smart-card applications ["New Breed Notebooks," April]. The machine also has a high-performance 32-bit electronic bus, or shared path for data. These IC cards, which offer between 1 and 20 megabytes of memory expansion—as much as some hard-disk drives—let you plug in prerecorded packages, such as electronic books. Data from cards can also be transferred into your personal computer.

Random House, another of Apple's selected partners, will create book titles for the cards. In the future, IC cards could make it possible for Newton to understand foreign languages. While the first-generation Newton will recognize only print and graphics, "technologies can be plugged in as they arise, such as cursive recognizers, so the machine will understand cursive writing eventually as well," explains Larry Tesler, vice president of Apple's advanced products group.

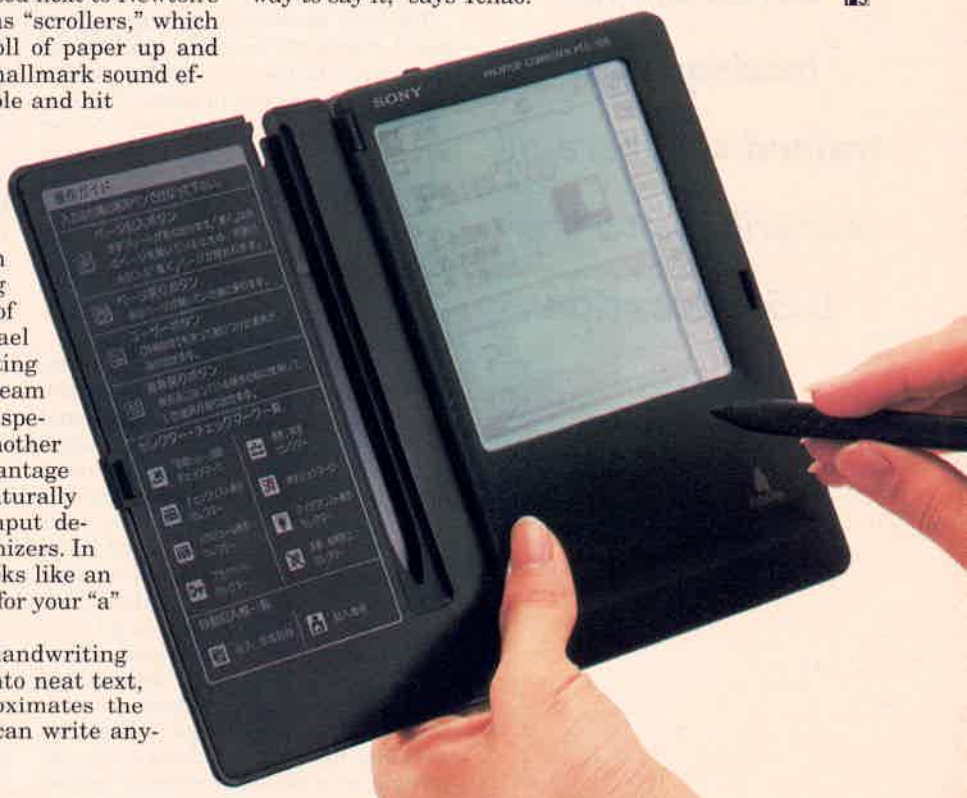
PDAs mimic reality: Arrows located next to Newton's on-screen control icons serve as "scrollers," which seem to move an electronic roll of paper up and down. Apple has added some of its hallmark sound effects as well: You hear paper crumple and hit the trash when you delete a document. Drawers open and close with a thunk when you file a document in Newton's electronic file cabinet.

Improved handwriting recognition also helps. Newton's handwriting recognition operates with groups of software "recognizers." Says Michael Tchao, manager of product marketing for the Newton group: "There are a team of recognizers, each with a different specialty. One team recognizes text, another graphics, or musical notes." The advantage here is that you can write more naturally than you could with current pen-input devices that don't use concurrent recognizers. In addition, if you write an "a" that looks like an "e," the notepad creates a recognizer for your "a" so it can be translated in the future.

The machine "cleans up" your handwriting and graphics, transforming them into neat text, graphs, and charts. Newton approximates the size of your handwriting, and you can write anywhere on the notepad as rapidly as you like. Apple's PDA also recognizes the spatial relationship of items on a page, which is ideal for mathematical equations, time lines, and flow charts. If you prefer notes with a handwritten appearance or dislike perfectly parallel parallelograms, the cleanup feature can be overridden.

Text and graphics can be combined without opening menus or cutting and pasting, steps that are necessary on most graphically oriented computers. If you draw a map, you can then label the street, just as you would on a notepad. To create a document, simply draw a line under what you've written and it's saved and filed in memory. "Think of Newton's screen as a continuous scroll of paper," explains Tchao. "You tear off sheets with a line as you go."

Newton's intelligent assistance capabilities make the device a helper rather than simply an organizer because it learns how you work (see Newton: The Information Taskmaster). Scribble a reminder to yourself—say, "lunch with Bob, Monday" on the screen—and the device logs the correct date and time into its calendar memory. In the near future, Apple aims to customize the machines even further by selling unique software to make them more useful. "Any profession has a standard set of forms. A doctor's Newton would look different from a lawyer's Newton," says Tchao. For instance, a doctor's Newton might be prescription-based, while a lawyer's Newton would contain legal documents. Artists, landscapers, architects, or anyone who is graphically oriented could make use of floor plans or blueprints stored in the device. "If a picture tells a thousand words, this is a great way to say it," says Tchao. PS



Sony Corp.'s PTC-300 PalmTop (right), available in Japan, uses Motorola's MC68000 processor. System software creates daily, monthly, or yearly agendas that track your appointments. Another new product entry, Sony's pocket-size PTC-300 computer, just released in Japan, also contains specialized software that transfers entered information immediately into a personal database, and tracks pending and completed appointments by making a checklist for you. The PTC-300 is a smaller version of Sony's initial pen-input PalmTop ["Computers Without Keys," Aug. '90].

CRISIS IN EDUCATION PART 2

WHY JOHNNY CAN'T DO

Poverty, discrimination against minorities and females, one-parent homes, poorly equipped schools, and inadequately trained teachers all contribute to the U.S. education crisis.

BY ARTHUR FISHER

A good many years ago a teenager named Mary Budd Rowe visited Princeton University. There she encountered an instantly recognizable figure. Albert Einstein. The eminent scientist was staring raptly at a fountain.

"He was tilting his head this way and that, and sometimes moving his hands rapidly up and down," she remembers. "I stood beside him, puzzled. He said nothing for quite some time. Then he turned to me and said, 'Can you do it? Can you stop the stream enough to see individual droplets of water?' "

Einstein showed the young student how to move her hands to synchronize them with the flow and create a strobe effect that froze the droplets. As they left the fountain, he told her, "Never forget that science is just that kind of exploring and fun."

Rowe, now a professor of education at Stanford University, has never forgotten; a major part of her mission has been to make the excitement and joy of discovery an integral part of science for children.

Others, however, must be forgetting—or perhaps they never learned. How else to account for the abysmal overall state of K-12 science and math education in the United States, one in which the achievement level of American high school graduates ranks near the bottom of the industrialized world and falls profoundly short of what is needed to succeed in a modern society? ["Science + Math = F," Aug.]

In thousands of American school districts, the teaching of science has virtually disappeared from elementary education. By high school few students find science classes fun, according to a 20-year research project carried out by the National Assessment of Educational Progress (NAEP). "Especially considering the technological needs of today's society," a 1990 NAEP report states, "a disproportionately low percentage of these students possess in-depth scientific knowledge."

The math morass is equally dismal. Eighth-graders have generally mastered no more than basic arithmetic and are weak in reasoning and problem-solving skills. Less than half of them can figure out the weight of a 30-pound object when it is taken to the moon, after being informed that moon weight is one-sixth Earth weight. The National Research Council has estimated that 75 percent of the nation's high school graduates are so poorly trained that they would flunk out of a college freshman math or engineering course.

The result is a massive, impending shortage of American scientists, mathematicians, and engineers. Walter E. Massey, director of the National Science Foundation, describes the problem this way: "Of every 4,000 seventh-graders in school today, only six will ultimately receive a Ph.D. in science or engineering. Of these six, only one will be a female.

"By the year 2000, minority students will account for 40 percent of our elementary and secondary school population. Yet 4 percent of undergraduate science and engineering degrees are awarded to minorities."

A study last year by the Council of Chief State School Officers showed that less than half of American high school graduates have taken chemistry and algebra II, both of which are considered crucial preparation for college work in math and science.

These are not merely intellectual or elitist concerns. What Lewis M. Branscomb has described as "a crisis become chronic" is a literal threat to America's national security and viability. Branscomb was the head of a task force on K-12 math and science education assembled by the Carnegie Commission on Science, Technology, and Government. Their report puts the case clearly:

"Inadequacies in precollege math and science education are a chronic and serious threat to our nation's future. The national interest is strongly bound up in the ability of Americans to compete technically. All young people, including the noncollege-bound, the disadvantaged, and young women,

SCIENCE AND MATH

must be given the opportunity to become competent in mathematics and science."

What has created these inadequacies? What is there about the American school system that produces students knowing less science and math than students elsewhere in the world? "Since our students are no less capable than those from other nations," says Betty Vetter of the Commission on Professionals in Science and Technology, "the data suggest that something in our values, our attitudes, or particularly our educational system demands special attention."

The answer is all of the above. The origins of our science and math troubles are longstanding. They include widespread social and economic problems—families living in poverty with little support or expectation of academic achievement; inadequate government funding and leadership; and a litany of flaws in the educational system itself. Among these flaws are poorly trained teachers; reliance on rote learning and outmoded teaching methods that ignore current knowledge on how children learn; ineffectual, over-ambitious text books; and curricula that try to jam impossible amounts of information into courses.

Social problems in America are primarily responsible for the millions of students who drop out before graduating from high school. In the year 2000, when the America 2000 goals set by the nation's governors and endorsed by President Bush call for American students to be first in the world in science and math achievement, one child in four will be poor, one in three will be a member of a minority group, and one in twelve will be so deficient in English as to require special help in learning.

Today, almost one in five children comes from a home in which no English is spoken, and one in three comes home from school to a house with no adult present to encourage doing homework. Sixty percent of the children born in the 1980s will live in a home with only one parent before they reach the age of 18. Every day in America, 40 teenage girls give birth to their third child. One in five high school students carries a weapon; in 1987, some 400,000 boys took guns to school. Many such children come to school with little motivation to learn and with little confidence that education will improve their future.

These conditions are not conducive to learning anything but failure and despair.

What goes on inside the home can, however, materially affect learning regardless of social or economic status. The NAEP's 1990 Science Report Card concluded that students performed better if they:

- had access to more reading materials such as books, magazines, newspapers, and encyclopedias
- read more than five pages for school each day
- spent at least some time on daily homework
- had both parents living in the home
- watched less television

The number of hours students watch TV corresponds inversely with their performance in a number of subjects, including reading. Reading is the essential substrate on which virtually all other learning—including science and math—is built. Yet 14 percent of American 17-year-olds are functionally illiterate. A 1992 NAEP report on reading ability found that many American children read fewer than 11 pages a day at home or in school and cannot capably analyze and interpret what they do read. They do, however, watch lots of TV. A quarter of fourth-graders, for example, watched the tube more than six hours a day; 40 percent of twelfth-graders watched more than three hours a day.

Commenting on the growing disparity, Secretary of Education Lamar Alexander counseled parents to encourage reading and limit access to TV. "It is not one of the national education goals," he said, "that we'd be first in the world in the amount of television our children watch, although it is one we're about to reach."

Much of today's educational crisis stems from the federal government's wildly fluctuating, stop-and-go attitude

MARY BUDD ROWE, PROFESSOR OF EDUCATION, STANFORD UNIVERSITY

"Science is a special kind of story-making with no right or wrong answers, just better and better stories."

WALTER E. MASSEY, DIRECTOR
NATIONAL SCIENCE FOUNDATION

"Of every 4,000 seventh-graders in school today, only six will ultimately receive a Ph.D. in science or engineering. Of these six, only one will be a female."

toward teaching science and math. When the Soviet Union launched the Sputnik satellite in 1957, a startled and alarmed United States reacted by disbursing money lavishly, turning the late 1950s and 1960s into a golden age of genuine but short-lived improvements in science and math education. But funding declined from 1968 to 1983, when it began another rise.

At the National Science Foundation, the annual budget for K-12 science and math education surged from $850,000 in 1956 to $13 million in 1958 and to $54 million in 1968. But by 1976 it had plunged to $7.5 million, and it bottomed at $3.8 million in 1982. In 1990, the budget was $125 million.

"Progress has been hampered," says Douglas Lapp, director of the National Science Resource Center, "because efforts in education have been driven by crises." Stop-and-go funding—and leadership—means it is impossible to have continuous, successful programs in science and math teacher training or in equipping classrooms with up-to-date laboratory equipment and computers.

States and municipalities pay 94 percent of educational costs, but the federal government's fiscal policies deeply affect local income. Federal direct aid to cities has fallen by more than 60 percent in the past decade. Combined with the current recession, the impact on many school districts has been devastating, as documented in a recent *New York Times* survey:

In one middle-income suburban Ohio elementary school, for example, students use science textbooks more than ten years old, have no laboratory glassware or hot plates for experiments, have lost half their computer access time, and make do with an encyclopedia set that's missing a volume. A series of funding cuts has deprived a school in a poor New York City neighborhood of the special science teacher it once had; a math teacher who used to spend three periods each day with gifted students now can see them only twice a week.

(In June, New York City schools chancellor Joseph A. Fernandez presented a blueprint for the reform of science education in the city's schools, with a focus on *all* students, rather than on the most academically able.)

The tremendous shortage of teachers who are well-trained in the latest, most beguiling teaching techniques has the most visible effect on how U.S. children learn science and math. Only 47 percent of high school math teachers majored in math in college. Two-thirds of high school science teachers majored in science in college—but not necessarily the same science they now teach. Whatever their educational background, most math and science teachers are simply ill-equipped to teach these subjects, according to the American Association for the Advancement of Science. Only 18 percent of elementary school math teachers and 14 percent of middle school math teachers have reached an established standard of course-work preparation. Of high school science teachers, only 12 percent in physics, 29 percent in biology, and 31 percent in chemistry met the standard.

What is worse, says the NSF's Luther Williams, is that "we lose 13 math and science teachers for each one who enters the profession. Many elementary school teachers say they are uncomfortable teaching math and science. That is not surprising. Many of them took only one or two courses in math or science while in college."

A National Research Council report found that too often, mathematics teachers are afraid that a student will ask a question they cannot answer. "Such insecurity," says Williams, "breeds rigidity, and leads to a 'cookbook' approach to math and science instruction—a deadly dull approach."

In fact, far too much science and math teaching is still done in the "transmission" mode, in which a teacher delivers information students are supposed to memorize and then regurgitate when called upon. Modern theories of learning rely on the approach called constructivism. Says Lauren Resnick of the University of Pittsburgh's Learning Research and Development Center: "Most of what we know we have to construct for ourselves. Human knowledge is not a photograph, metaphorically speaking, of something out there, not just a record of what we are told or what we see. We have to put it together in order for it to work for us."

Children begin to learn science from the moment they become aware of their environment. They are born with an imperative that says, "Make sense of what is going on." And they build models of the real world through constant and repeated operation and experience, models that help them to understand what they have seen and heard and to predict what may happen next.

What this means is that the teaching—and learning—of science and math should rely on a "hands-on" approach, emphasizing experiment, discussion, cooperation, and participation. Yet only 33 percent of eleventh-graders have used an electrical meter, only 59 percent have ever written up the results of an experiment, and only 20 percent have ever gone on a science field trip.

A NATIONAL ACHIEVEMENT TEST?

In 1991, President Bush called for the establishment of voluntary national tests —the American Achievement Tests—as part of his announced intention of assuring the preeminence of American high school graduates in science and mathematics by the year 2000. The tests would be given in math, science, history, geography, and English to grades 4, 8, and 12..

The administration will urge not only college administrators but also businesses to use an applicant's test scores on these exams as a guide to admissions and employment. Moreover, Secretary of Education Lamar Alexander envisions a new program of federal scholarships that would be awarded on that basis.

Exactly what the tests' format will be like, who will determine their content, how long they will take to be developed, and how much they will cost to administer remain to be decided. It is likely, however, that they will eschew the traditional multiple-choice, short-answer route now taken by most achievement tests. If the Administration's plan does go forward, it might take five to seven years to develop the tests and cost about a billion dollars a year to administer them.

Some critics feel that the impositions of such national tests, voluntary or no, could lead to the establishment of a national school curriculum, and a damping of the intellectual diversity that is vital to education. Three groups of testing experts—the American Psychological Association, the American Educational Research Association, and the National Council on Measurement in Education—have jointly warned that the rush to establish a national exam or assessment system could ultimately damage the nation's school system. Last January, more than 50 prominent educators issued a statement opposing a single national test. And a recent report of the congressional Office of Technology Assessment stated that unless key questions about the design, uses, and governance of a national test and the interpretation of its results are stressed, a system of national tests could easily become a barrier to educational reforms and spur a new round of frustration with the education system.—*A. F.*

"For years," says Milton Goldberg, a director of research for the Department of Education, "science and math educators have espoused hands-on learning. However, student experiments and hands-on assignments have [actually] declined in recent years. Students spend more time in lectures or reading about science in textbooks than actively participating in science. Time spent in laboratory work is declining."

The reasons for not using hands-on methods? They cost money, and teachers must have the background and training to use them. Goldberg also complains that the science and math textbooks that dominate the curriculum are outdated and inadequate.

Stanford's Mary Budd Rowe decries the current reliance on the rote learning of science "facts," which she says derives from America's "fantastic drive to do testing" (see A National Achievement Test?). High school science courses, she says, introduce on-average more vocabulary than a first-year foreign language course.

The prescribed school year's reading in a typical science text—300 to 350 pages—means that students must memorize a staggering 2,400 to 3,000 new terms. Twenty new concepts would have to be covered per class period, an average of one every two minutes. That leaves almost no time for discussion or inquiry. Rowe remembers a frustrated student who slammed down his ultra-thick earth science text, crying "It's a damn dictionary! Who reads dictionaries?"

"Science books have turned into fancy dictionaries," says Rowe. "The plot, the story line—the way in which ideas interact—have disappeared. Science is a special kind of story-making, with no right and wrong answers, just better and better stories. You live with the best story you have at the moment."

Too often, however, the national hunger to test has perverted the image of what science is. "In today's schools," says Rowe, "the students' primary responsibility is to learn the official story well enough to write it or recite it correctly, regardless of whether they understand it."

To combat this deadening, oppressive approach, scientists and mathematicians, federal agencies, universities, and businesses are collaborating to launch new programs that train teachers in hands-on science and math learning (see Teaching Teachers to Teach). The scale of these local programs is dwarfed by the size of the problem overall; but they show what could be achieved nationally if enough will, expertise, and money were applied. Some of these programs specifically address the problems of school systems with large or predominantly minority populations. Not only are minorities the most educationally disadvantaged in science and math, but by the year 2000, more than half of those retiring from the work force will be white males, while 70 percent of those entering the work force will be minorities, women, and immigrants.

Parallel to the "minority gap" in

"Human knowledge is not . . . just a record of what we are told or what we see. We have to put it together in order for it to work for us."

LAUREN RESNICK, CODIRECTOR, LEARNING R&D CENTER, UNIVERSITY OF PITTSBURGH

math and science exists a gender gap. Today, women represent 45 percent of the total U.S. work force, but only 13 percent of the nation's scientists and engineers. In the fourth grade, girls and boys do about equally well in science and math. But girls lag as they move up through the grades. Education Secretary Lamar Alexander says that "cultural attitudes" convey the message of inherent inferiority in science and math to girls. That message is not just cultural, but is actively reinforced in the schools, says a report titled "How Schools Shortchange Women," commissioned by the American Association of University Women.

Among the subtle and not-so-subtle ways that bias is exercised: Teachers pay less attention to girls, calling on them less often than boys and offering them less constructive criticism; textbooks stereotype women, with few female scientists and mathematicians presented as role models; some tests are biased against girls by using examples with dominantly masculine themes such as football; and there exists considerable sexual harassment, especially for girls who perform well in science and math. The result, the study shows, is that even girls who excel in science and math tend not to choose the fields for a career.

Unfortunately, says Stephen G. Brush, a professor at the University of Maryland, there is a shortage of qualified women science teachers who might counteract the stereotypical view of women scientists and engineers as unattractive and unfeminine and belie the ubiquitous belief that women are inferior to men in mathematical ability. He observes that women's participation in science seems to be leveling off; the number of women earning technical degrees, after increasing from the 1960s to the early 1980s, has plateaued.

"Teachers can't teach science because they're terrified of it."

LEON LEDERMAN, NOBEL LAUREATE IN PHYSICS

Last September, the Carnegie Commission recommended greater federal leadership, urging that the Department of Education, the National Science Foundation, and all other science agencies help states and cities reach the new, ambitious America 2000 goals. The Commission recommended that the federal government designate a part of its hefty $68 billion federal science budget to aid math and science education. If only 1 percent of that budget were allocated, it would more than double the amount of funding that is now aimed directly at science and math education.

"There is no shortage of motivated Americans with good ideas about how to serve our children better," says Lewis Branscomb. "But the federal government is not yet organized to bring to every classroom in America the best of the ideas—how to restructure the schools and motivate students and teachers, and how to provide teachers with the tools and training they need."

The situation is exacerbated by the existence of more than 15,000 local school districts and 80,000 schools serving some 46 million children in grades K-12, a system with an almost total decentralization of authority and in which the distribution of resources is, to put it mildly, nonuniform. "Local control of public schools may have its virtues, writes Margaret L. A. MacVicar, dean of undergraduate education at Massachusetts Institute of Technology, "but the capacity for rapid change in response to national needs is not one of them."

A step in the right direction came this May, when NSF director Massey announced the federal government's most sweeping effort in science and math education since President Bush's 1989 education summit with the state governors. California, Georgia, Kentucky, Maine, Massachusetts, Michigan, New Mexico, Puerto Rico, Texas, Vermont, and Virginia were selected to receive funds for a systemwide reform of science and math education in grades K-12. The grants total $100 million for up to five years.

"This Statewide Systematic Initiative," Massey declared, "is different because it is comprehensive and it requires a very high degree of participation by key education leaders and by parents. Past attempts to reform science and math education have focused only on part of the educational system. The SSI program brings together governors, state and local education leaders, businesses, parents, and other community leaders. By working together, this partnership can make a real difference."

In the SSI program, both teachers and students spend time in research laboratories, experiencing firsthand the possibilities and the limitations of science and math in solving real-world problems. Scientists from Department of Energy laboratories, for example, will develop partnerships with schools in Virginia and help analyze global climate data from satellites. Scientists from federal labs in New Mexico will spend some time each week as consultants to teachers. And partnerships between schools and companies like IBM and New England Telephone will bring advanced technologies and equipment into classrooms in Massachusetts, Georgia, and Vermont.

These are just the sort of scientist-teacher partnerships that flourished

in the form of NSF summer institutes in the post-Sputnik years, but were eliminated during the Reagan administration, "ostensibly," says Timothy H. Goldsmith, professor of biology at Yale University, "because they were deemed ineffective in improving student test scores."

Behind all of these efforts to upgrade the achievements of U.S. students lies a nagging question. What exactly do we mean by science and math achievement and just what do we want high school graduates to know about these subjects? The answers to those questions must determine what is taught, and learned, in the classroom. Says Francie Alexander, a member of the National Assessment Governing Board: "If you don't even have agreement on what kids should know, what does it matter?"

Until recently, there has been little agreement and much debate, with a resulting hodgepodge of school curricula—the rules that specify what and how to teach and in what grade to teach it. Children in one locality may leave sixth grade knowing how frogs reproduce but not the difference between alternating and direct current, while somewhere else the opposite may prevail.

That chaotic situation is beginning to change. Teachers, professional scientists and mathematicians, and concerned citizens are coming together to forge what can best be called standards in science and math. Rather than specifying in numbing detail just what happens during the school year, a standard specifies what students should know and be able to do at various age levels, listing milestones, say, instead of accounting for every foot traveled.

Just such a standard now exists. Published in 1989 by the National Council of Teachers of Mathematics, it sets curriculum standards for grades K-4, 5-8, and 9-12. Each standard within the grade division is copiously illustrated with examples. The standards emphasize the development of children's thinking and reasoning abilities from kindergarten on, call for the appropriate use of calculators and computers, and specify what should be known at each stage for a broad range of content: measurement, computation, geometry, algebra, and—in what will be startling to many parents and teachers—statistics and probability, beginning in kindergarten.

Shirley A. Hill, professor of mathematics and education at the University of Missouri and a key player in the development of the new standards, described them this way: "There has been a long-time consensus about making mathematics-learning more about thinking and engaging the intellect and less about memorizing; more a task for the mind than a test of rote memory. That basic philosophy is now manifested in detailed and specific terms in a document that is the centerpiece of the profession's reform effort in mathematics."

Perhaps the most impressive fact about the new math standards is that they have been accepted nationwide by a constellation of education constituencies: teachers, supervisors, unions, parents, school boards, professional societies, politicians, and university faculties.

That this consensus was achieved bodes well for the present effort to do something similar for science. This will be a much more daunting task simply because science is fractured among many disciplines, often with competing agendas and ambitions. John Rigden of the National Science Standards Project is confident the effort will succeed. Participants in the

[*Continued on page 98*]

TEACHING TEACHERS TO TEACH

"Teachers can't teach science because they're terrified of it," says Nobel laureate Leon Lederman. "Science is postponed to the last two periods and then everybody prays for a fire drill." Lederman, formerly director of Fermilab, was instrumental in the formation of the Teachers Academy for Mathematics and Science, which is based on the campus of the Illinois Institute of Technology in Chicago. Opened in 1990, it is a major effort to deal with the problems of Chicago's 18,000 K-12 science and math teachers in a school system with 400,000 students, most of them minorities.

A key item in the training of teachers at the academy is the integration of teaching and learning—science teachers must learn science in the same way that they will teach it, as an integrated subject with mathematics, physics, chemistry, biology, and earth science learned in a comprehensive and coordinated classroom. Elementary school teachers leave their classrooms for 16 weeks at a time to learn to perform experiments that will eventually charm and engage their students.

The academy uses a K-8 hands-on, experiment-based program called TIMS, for Teaching Integrated Mathematics and Science, which has been developed with grants from the National Science Foundation. In it, students collect, organize, graph, and analyze data, seek the patterns in the data, express these patterns mathematically, and then make inferences and predictions based on the results. There are more than 80 TIMS experiments for grades K-8.

The first-year budget of $5 million enabled the academy to give intensive training to most of the teachers in ten of Chicago's 596 public schools. The program, which if fully implemented would cost an estimated $30 million a year, has strong federal, state, and local support.

A few innovative programs aim to redress the fundamental imbalance in science and math learning between white males on the one hand and females and minorities on the other. One outstanding program for minorities is MESA (Mathematics, Engineering, Science Achievement), a pre-college project headquartered at the University of California at Berkeley. There are 20 MESA centers that administer MESA programs in 240 schools spread over 70 school districts. On the Berkeley campus, fourth- through twelfth-graders from Berkeley, East Oakland, and Richmond, where some of the poorest and academically lowest-achieving children in the San Francisco area live, participate in a four-hour session every Saturday over a nine-week semester for integrated study of math, science, and English. The aim is to promote problem-solving, an understanding of concepts, and cooperative learning.

"The philosophy that all children, and not just a select few, are highly talented and capable if taught in the right way," says one MESA teacher, "could be used by any teacher with children from any background. The brains of the kids are not the problem."

More than 10,000 students enrolled in MESA programs for the 1990-1991 academic year, a majority of them black and Mexican-American. More than half were female. Since 1981, the project has helped to turn out more than 7,000 high school graduates and some 2,000 engineering graduates.—*A. F.*

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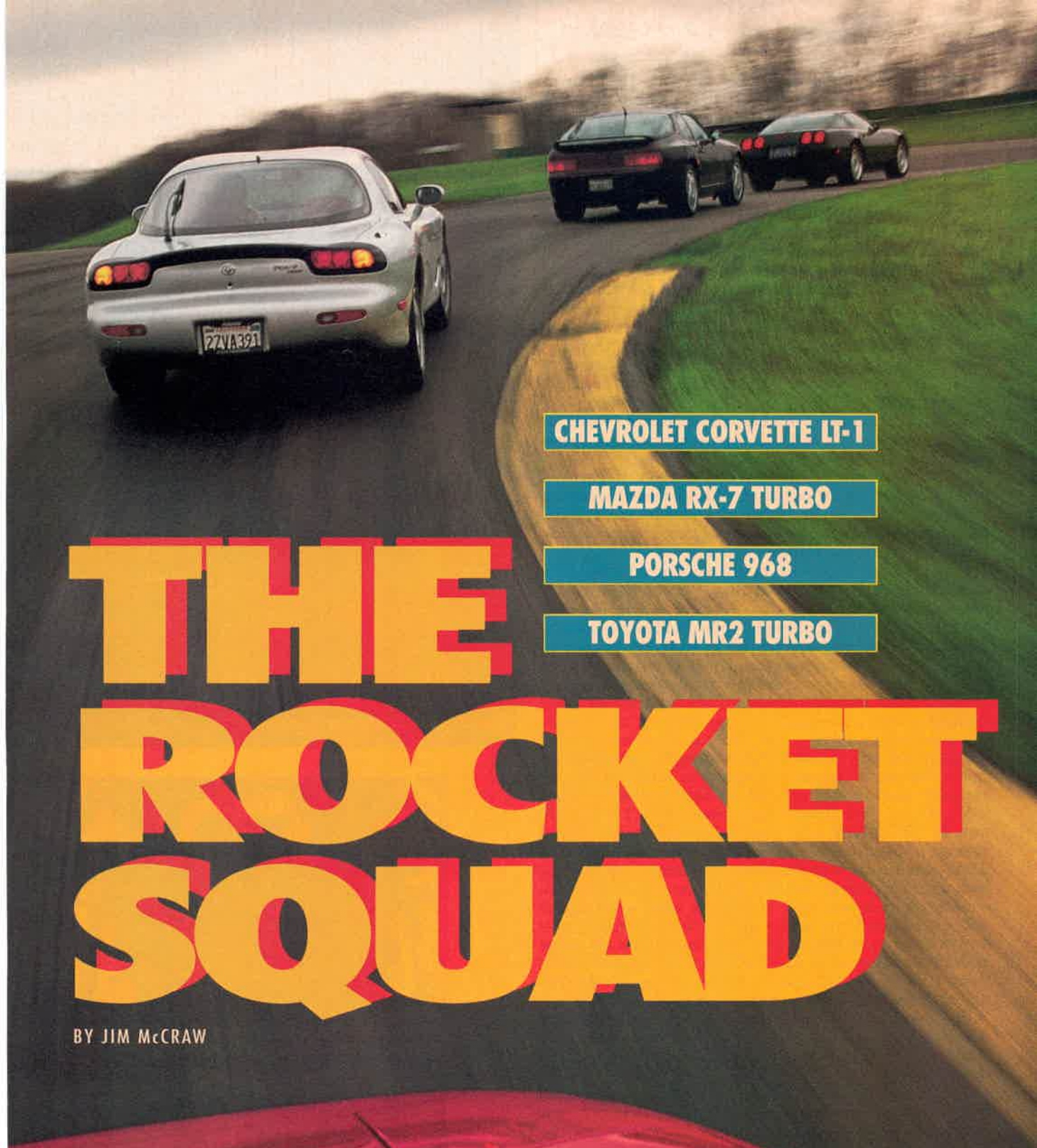

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MAZDA RX-7 TURBO

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THE ROCKET SQUAD

BY JIM McCRAW

Today's technology has added power, roadholding, comfort, and speed to out-and-out sports cars. Four of the best return to their roots—this time with air-conditioning.

There was a time when the cars that ran at Grattan Raceway, a winding, hilly two-mile road course up in Michigan's Hemingway country, were driven to the track and driven back home. Back then, that was what a sports car was all about—a car to be raced, with amenities, seating, and weather protection just sufficient to make it tolerable on the highway.

Those priorities seemed reversed as the POPULAR SCIENCE test team drove northward toward Grattan in a drizzle with four of the most proficient two-seat sports cars on the market today: the new Mazda RX-7 turbo, the Chevrolet Corvette LT-1, the Toyota MR2 turbo and the new Porsche 968. We cruised with draft-free tops; antilock brakes and traction control; complex sound systems; even (gasp!) air-conditioning. Back-country Sports Car Club of America (SCCA) racing has changed, and so have sports cars. Still, the opportunity to push these cars to the limit where MGs, Alfas, and rear-engine Porsches once held sway was irresistible. With today's technical sophistication, have sports cars matured or merely gone soft?

Grattan is a beautiful ten-turn road course with plenty of everything, including ponds, livestock, woods, elevation changes, runoff area, and some very challenging corners. Built in the mid 1960s, it's still mainly used for motorcycle and SCCA racing and testing.

Turn Three at Grattan is a downhill left-hander that goes abruptly up a short chute to Turn Four, a right-hander where airborne maneuvers are common. Going downhill fast into a tight turn and then uphill tests tires, suspension, steering, brakes, and courage all at once. We decided to time each car through these turns from approach to exit as a further measure of sports car prowess, beyond our normal handling tests. Here, all systems of the car are used: hard braking on entry, some simultaneous braking and cornering, some pure cornering, and heavy acceleration and cornering on the exit. To add to the challenge, it rained briefly in the morning on test day, providing us with a perfect opportunity to check both wet and dry handling and braking.

We started with Mazda's rotary-engine RX-7 coupe, all-new for 1993. Mazda engineers had to look for ounce-level savings in hundreds of places in order to come up with a 2,840-pound coupe with the ideal 50:50 front-to-rear weight balance. This process resulted in dozens of new ideas, including an extremely stiff and strong computer-designed body-chassis unit and a very tiny, lightweight cooling system-radiator combination. Even the floor pedals are made of drilled-out bare aluminum castings with no rubber pads. Almost all of the full upper and lower control-arm coil-spring suspension is made of forged and cast aluminum.

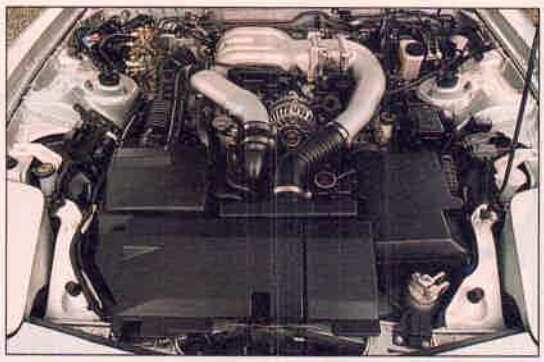
The interior includes a glorious instrument panel with '50s-style chrome bezel rings; the exterior has a wonderful shape, deliberately redolent of 1960s British and Italian sports cars.

The all-new engine is still only 1.3 liters, measured as twice the displacement of a single rotor chamber—not equivalent to piston-engine displacement. It now has two turbochargers, plumbed sequentially into the engine's induction system. The additional boost and fuel are programmed to start at about 5,500 rpm and build from there. This compact solution to the power problem develops a very respectable 255 horsepower at 6,500 rpm with 217 pound-feet of torque at 5,000 rpm, and winds to 8,000 rpm with that unique rotary howl.

The RX-7 is truly wonderful once warmed up. The engine's smoothness and power couple up to a slick five-speed transmission. The ventilated disc antilock brake system is nothing short of sensational. Helped along by the big tire footprints and light weight, the RX-7 was nearly equal to the shortest stops we have ever seen—as low as 117 feet from 60 mph.

PHOTOGRAPHS BY JOHN B. CARNETT

New comfort features set off (from left) Mazda's RX-7, Toyota's MR2, Porsche's 968, and the new Corvette from their spartan predecessors.



Mazda's compact RX-7 rotary power plant is nearly lost in the tiny engine compartment, twin turbos and all.

The transverse, turbocharged mid-engine layout of the MR2 results in a rear-weight bias and predictable understeer.

Porsche's huge three-liter in-line four-cylinder is powerful and smooth due to balance shafts that offset shaking forces.

Reverse-flow cooling and a revised manifold bring the LT-1 V8 up to 300 hp—phenomenal for a two-valve pushrod design.

The Mazda RX-7 is not without some problem areas, though. It's not the easiest car to drive smoothly. The sequentially turbocharged and intercooled, fuel-injected rotary engine has very tricky throttle response, both on- and off-throttle, because it has low rotating mass coupled to a very light flywheel.

The light flywheel effect makes the engine herky-jerky and the car especially hard to launch, with the result that the engine either stalls, so you're constantly tempted to use higher and higher revs and blip the engine, or it catches too hard and spins the tires.

The ride in the RX-7 is seriously sporty. It's a bit harsh and the car is cramped inside, though the seats are well shaped and supportive enough for long hauls. (We would have chosen wider seats and a narrower console between them for American drivers.) The door handles, open-ended paddles integrated with the doors, don't work well. The doors never latch on the first try, either, because of the stiff noise and dust seals used around their perimeters.

The extensive work done on the RX-7 was the most comprehensive reengineering of any car in the group. In contrast, the major change for the 1993 Toyota MR2 is a revised suspension aimed at curing the unpredictable tail-happiness that plagued earlier generations. The MR2 now is in its third incarnation since the middle '80s. The improved 1993 model has the looks, the handling, and all the power and power-assist equipment you could want in a two-seat sports car priced at less than $30,000.

Overall, the changes have improved the car, and we liked the MR2 turbo better each time we drove it. The lateral links have been lengthened and the trailing arms relocated

ROTARY REIGNS OVER ALL

I think plenty of customers will enjoy driving the Toyota MR2, a Ferrari-in-disguise for the price of a loaded Camaro. Still, these cars drive me to the conclusion that God never intended a supreme-handling sports car to be mid-engined. A quick and nimble turn is hard to accomplish when there's a chance that the rear traction will wash out because the rear tires are burdened with power delivery and a preponderance of the car's weight. With the new suspension revisions, the new MR2 is forever locked in the understeer mode, which to me is as bad as excessive oversteer.

The Porsche 968's most horrendous fault is the transmission pattern. It has no other major failings but has fallen behind in performance. The chassis is nicely balanced, but there's a bit too much understeer at the limit, and the limit is lower than the other three cars. With 150 pounds less weight and $10,000 less price, this car would start to make some sense.

The Corvette is still fun after all these years, but what a pain to enter, exit, and exercise. I give the Corvette credit for its improved engine, nifty ASR (anti-slip regulation) traction system—which is great for wet driving—and predictable poise. Where it falls down is the cost relative to the effort involved in driving.

The beauty of the Mazda RX-7 is its light weight. It influences every driving aspect in a positive manner. Even though this Mazda isn't the quickest in acceleration or the stickiest in maneuvering tests, it was by far the fastest on the racetrack. It has the most aggressive and satisfying turn-in, crisp steering, and brakes that don't lock and disturb the chassis. Good performance for the price and fresh and attractive styling combine to make the RX-7 a joy to exercise.—*Don Sherman*

slightly higher than on the 1992 version. According to Toyota engineers, these two tweaks change the rear suspension's toe-in curve as the wheel travels from full compression to full rebound.

Driving the MR2 on a really good piece of road brings out the boy racer after about two turns of the wheel, in part because it is the only one of the cars in this test with a so-called "exotic" layout: mid-engine, rear-wheel drive with lots of power, and 57 percent of the weight on the driving wheels.

The MR2's infamous oversteer has been replaced by a hefty amount of understeer, due to tire and suspension adjustments. The MR2 is a lot of fun for the money. It accelerates to 60 mph in well under seven seconds, runs a 90-mph quarter-mile, and tops 140 mph on the road while slithering its way through the twisty parts.

A workaholic turbocharged four-cylinder four-valve engine generates 200 hp and 200 lb.-ft. of torque—the lowest output in the group. The engine responds enthusiastically, due to a combination of good basic breathing plus turbocharging. This engine is a high-winding, medium-boost combination that makes sports-car driving the joy it's supposed to be.

The 1993 transaxle has been fitted with a shorter shifting lever and multiple-cone synchronizers on both second and third gears for improved feel and performance, but we found that the fix needs fixing. The linkage doesn't feel as good as the original MR2 shifter.

Although there is obviously some engine noise intrusion—about 87 decibels at full throttle—it's not as bad as the rather high decibel number suggests, because what is generated back there is more like sound than noise. Normal cruising is quite good for a rear-engined sports car.

From the Porsche factory in Germany comes the 968, a mixed bag of sports-car parts if ever there was one. The 968 has evolved from the 944 that debuted in the early 1980s. The 944 evolved in turn from the 924, that collaboration of a Porsche and an Audi engine that debuted in 1976, positioned between the nasty 911 and the gentleman's express 928 V8.

Today's 968 design started with about 80 percent of the old 944. Porsche borrowed uncovered pop-up headlamps from the 928, added a few other items from the four-wheel-drive 959 racer and the 911, then blended in the 944's engine package, huge power ventilated disc antilock brakes, a six-speed manual transmission, and two air bags.

At three liters, the 968 engine is one of the world's largest production four-cylinder passenger-car engines. The all-aluminum alloy four-valve, fitted with Porsche's variable valve timing and twin balance shafts, makes 236 hp at 6,200 rpm and 225 lb.-ft. of torque at 4,100 rpm. Porsche alleges the latter figure is the highest torque rating of any normally aspirated four-cylinder. Above 5,000 rpm the engine is as charismatic as a Kennedy and has the power of a musk-ox.

Porsche has done a California customizing job on its 944, stuffed it with power, and kept the already wonderful chassis. Among the things we liked best about the 968 were the engine and the steering. The huge four-cylinder makes enough power to reach 60 mph in six seconds flat and about 153 mph topped out.

The 968 is confidence-inspiring and therefore a lot of fun to drive at speed and very pleasant in all situations except low-speed ones, where its engine has little grunt. That leads to the transmission, with a shift pattern that places first, reverse, and third in close proximity without a lockout for reverse. Shifting into reverse at stoplights is no fun, and neither is downshifting from fourth to third and getting first instead. Reverse gear really should be put on the other side of the pattern with fifth and sixth gears.

While we were not happy with the transmission, the engine was terrific, if a bit rough and loud at high rpm. Handling, likewise, was well-mannered and secure—linear, reassuringly heavy and direct-feeling with a tiny bit of deadness at center, precise in the corners, but still understeering at the limit. The ABS felt like the racing brakes from which they descend—strong indeed, with great pedal feel.

On the inside, though, we consider the Porsche 968 seriously flawed. Our test car came with impractical off-white seats, door panels, and carpeting, none of which will ever look clean again once sullied. And the seats, considering the kind of car the Porsche is, were marginal at best—not as good as the seats we remember from years ago in the 944 turbo. (Recaro sports seats are optional.)

The instrument panel is another disaster, with no particular pattern or rhyme or reason to switch and control placement. The trip odometer reset button is located at the center of a ventilator control. There is a huge tachometer and speedometer in the instrument cluster, and the

cluster itself is easy to use, but the rest of the ergonomics and controls inside the car are pretty dreadful for a world-class sports car manufacturer.

It's clear the 968 is a bargain tune-up on the old 944, but not nearly at a bargain price. At an as-tested price of about $45,000, it's Porsche's least expensive car. The 968 did not achieve a clear victory in any single performance test. Considering what the other sports cars can do for $10,000 to $15,000 less, the 968, even though it is a high-quality, solid-performing sports car, is a bit behind the curve.

The standard Corvette has had a heart transplant before its 40th birthday. The Chevrolet 5.7-liter, overhead-valve, small-block V8 engine was reinvented last year with the advent of the LT-1 engine, with updated components and 300 hp on tap—much closer to the look, feel, and performance of the $66,000 ZR-1 Corvette, at half the price. The LT-1 Corvette comes with a six-speed transmission, all-aluminum upper and lower control arm suspension, ABS, and ASR (anti-slip regulation, a computer-controlled traction-enhancing system).

After many years of refining and tweaking, the fiberglass Chevrolet Corvette's quality is much better, but its ride quality is still trucklike under some road conditions. Even the Corvette's electronically adjustable shock-absorber system doesn't help much. Regrettably, there are still squeaks and rattles that need to be chased down and eradicated —different ones, it seems, in each car.

The Corvette offers a completely different set of ergonomic problems than, say, the Porsche. A long-wheelbase car, the Corvette is very low, with wide, heavy doors, wide sills, and a sunken seat, making it hard to enter and exit. It has a fat mid-body shape, putting bodywork next to your face where there should be glass. The dashboard extends back into the cab and even with a tilt/telescope steering wheel and power seat adjustment available, the car always seems cramped. Foot room is at a premium. The amber-colored digital instruments are confusing and hard to see in bright light.

That list of niggles aside, the Corvette's 300 hp and stout 330 lb.-ft. of torque handle the car's 3,360-pound bulk with ease, propelling it to 60 mph in a flash—5.2 seconds—and within a whisker of its 160-mph top speed. The engine makes so much torque that a two-speed transmission would do nicely. But it has six speeds and rowing through them is about 75 percent of the car's charm, with handling and looks accounting for the remainder.

Stiff springs, shocks, anti-roll bars, and huge tires are needed to deal with the momentum the Corvette can develop. The drivetrain and the suspension/tire combination render a durable, heavy-duty sports car that can win races and set records, but isn't much fun to live with when you're not on the gas and setting up for the next apex. Its basic handling envelope is a large one, helped by Goodyear GS-C tires and the ASR system, which keeps the tail in line under most conditions and works wonders in the rain. What would the Corvette be like, we wonder, if it were a foot shorter and weighed 520 pounds less like the RX-7?

At the end of the day, the rear-engined Toyota MR2 proved to be the best at abrupt handling situations, such as the 600-foot slalom and the double-lane change. But the RX-7 won our Turn Three exercise and covered almost the entire field in braking. The Corvette won the acceleration battle by a tick.

The fastest complete dry lap also went to the RX-7, by more than 1.8 mph over the Corvette, followed by the Toyota and the Porsche—which trailed in just about every test except price-tag-cardiac effect. While the Toyota is a real sports-car value, and the Corvette is certainly the heavyweight champion, this year's most significant sports car is the lightweight, back-to-basics Mazda RX-7. PS

POPULAR SCIENCE TEST RESULTS

	Chevrolet Corvette LT-1	Mazda RX-7 turbo	Porsche 968	Toyota MR2 turbo
ACCELERATION and HANDLING				
0-30 mph (sec.)	2.6	2.6	2.4	2.1
0-60 mph (sec.)	6.7	6.0	5.8	5.2
30-50 mph (sec.)	9.4	11.0	11.8	10.1
50-70 mph (sec.)	7.7	9.1	9.5	9.5
Double-lane change (mph)	64.6	61.5	64.1	61.3
Slalom (mph)	52.2	50.6	51.1	49.9
BRAKING				
Cold (ft.)	134	138	121	137
Warm (ft.)	133	130	117	123
Hot (ft.)	130	131	118	125
Wet (ft.)	153	150	143	142
INTERIOR NOISE				
Idle (dB)	46	55	45	50
60 mph (dB)	71	72	71	71
0-60 mph (dB)	87	81	83	84
RACETRACK SPEED				
2-mile Grattan Raceway (mph)	70.8	70.7	73.5	71.7
Turn Three (mph)	44.2	43.4	45.2	44.1
SPECIFICATIONS				
Engine	2.0L I4	3.0L I4	1.3L 2-rotor Wankel	5.7L V8
Valve train	DOHC; 4 valves/cyl.	DOHC; variable valve timing; 4 valves/cyl.	3 valves/rotor	Pushrod 2 valves/cyl.
Power (hp @ rpm)	200 @ 6,000	236 @ 6,200	255 @ 6,500	300 @ 5,000
Torque (lb.-ft. @ rpm)	200 @ 3,200	225 @ 4,100	217 @ 5,000	330 @ 4,000
Compression ratio	8.8:1	11.0:1	9.0:1	10.2:1
Transmission	5-speed manual	6-speed manual	5-speed manual	6-speed manual
Final drive ratio	4.29	3.78	4.10	3.45
CHASSIS				
Front suspension	MacPherson strut, coil springs, anti-roll bar	MacPherson strut, coil springs, anti-roll bar	Unequal length control arms, coil springs, anti-roll bar	Unequal-length control arms, transverse plastic leaf spring, anti-roll bar
Rear suspension	Independent, strut-type, coil springs, anti-roll bar	Independent, semi-trailing arms, torsion bars, anti-roll bar	Independent, multi-link, coil springs, anti-roll bar	Independent, multi-link, transverse plastic leaf spring, anti-roll bar
Steering gear	Rack-and-pinion, electro-hydraulic power assist	Rack-and-pinion, power assist	Rack-and-pinion, power assist	Rack-and-pinion, power assist
Turning circle (ft.)	32.1	35.3	35.4	40.0
Brakes (front, rear)	ABS; vented disc, disc; power assist; power assist	ABS; vented disc, vented disc; power assist	ABS; vented disc, vented disc; power assist	ABS; vented disc, vented disc; power assist
EPA MILEAGE				
City (mpg)	20	17	17	16
Highway (mpg)	27	26	25	25
DIMENSIONS				
Wheelbase (in.)	94.5	94.5	95.5	96.2
Length (in.)	164.2	170.9	168.5	178.6
Width (in.)	66.9	68.3	68.9	71.0
Height (in.)	48.6	50.2	48.4	46.7
Curb weight (lbs.)	2,920	3,120	2,840	3,360
Distribution % (front:rear)	43:57	49:51	50:50	52:48
Fuel tank (gal.)	14.3	19.6	20.0	20.0
Interior volume (cu. ft.)	49.9	63.0	48.1	48.7
Trunk volume (cu. ft.)	6.5	12.0	13.6	12.6
PRICES, PARTS, AND LABOR				
Base price	$21,218	$39,850	$31,300	$33,635
Price as tested	$26,347	$44,915	$34,300	$38,789
Major options (over $100)	CD sound system $1,150; ABS $1,130; air conditioner $870; power steering $600; power package $495	Cast aluminum wheels $1,352; radio with CD player $1,347; limited-slip differential $895; metallic paint $803; leather seats $668	Touring package (contains leather upholstery, power sunroof, cruise control, Bose Acoustic Wave sound system) $3,000	Selective ride and handling $1,695; preferred equipment group $1,333; leather sport seats $1,100; CD player $396; tire-pressure warning system $325
REPAIR: PARTS/LABOR*				
Front brake pads	$ 47/45	$ 125/47	$ 95/27	$ 64/31
Front shock/insert	130/153	217/47	140/27	59/22
Alternator	473/45	852/105	250/59	208/66
Water pump	75/293	375/286	70/131	198/62
Windshield	365/225	548/216	392/180	774/185
Headlamp assembly	18/36	160/58	135/18	41/13

*Labor costs reflect manufacturer's flat-rate time allowance multiplied by typical dealership labor rates per hour.

DIGITAL PHOTOGR

A new generation of filmless electronic cameras is changing the way images are created, transmitted, and manipulated.

BY DANIEL AND SALLY GROTTA

Midnight was fast approaching, and *USA Today* was minutes away from going to press on the East Coast just as Anthony Hopkins, Jodie Foster, and *The Silence of the Lambs* were making their sweep at the Academy Awards, 2,700 miles away. If the photographer had been using a conventional 35mm camera, there would have been no way that the newspaper could make its deadline and still include color photos of the winners holding up their Oscars. That's why *USA Today* shot the ceremonies with a Sony Mavica MVC-5000 still-video camera.

Immediately after the photographer shot the Oscar winners in Los Angeles, he removed the two-inch disk from the Mavica and inserted it into a Sony portable still-image transceiver, a book-size device that converts the images from an analog to a digital signal, compresses the files, and transmits them over a standard telephone line at the rate of one image every two minutes. The pictures were automatically sent directly to a Macintosh computer at the newspaper's offices in Arlington, Va. Once received, they were converted into a file format compatible with the Associated Press's Leafdesk Picture Desk system and then edited, cropped, and stored. The photographs selected to appear in the next day's edition were then transferred to the multimillion-dollar Scitex page-composition system, which *USA Today* uses for page layout and to make the printing plates.

Except for the final Scitex output—color separations for the printing presses—the entire process was completely electronic. With a still-video camera and an imaging system running at warp speed, it was only a matter of minutes from when the photographer clicked the shutter and the presses rolled with the finished picture.

"We used the Mavica for the Academy Awards because it is virtually instant photography," explains Frank Folwell, *USA Today*'s assistant director of photography and the paper's resident electronic-imaging guru. For the past three years, *USA Today* has employed various still-video-camera systems to cover other deadline-hugging events, like the World Series, the Super Bowl, and the Grammies. "We've even tested them with satellite and cellular phones, because it's possible to hook up to a telephone anywhere in the world and have your images back immediately," says Folwell.

Welcome to the brave new world of digital imaging, a process that uses silicon rather than silver and a computer instead of a darkroom. In other words, it's the process of using computer technology to capture, create, and/or manipulate photolike pictures in which reality can easily be changed.

Using the $10,000 Mavica is, in most respects, identical to shooting with a conventional camera. Like most professional cameras, the Mavica is a single-lens reflex that can operate in either the automatic or manual mode, accepts a

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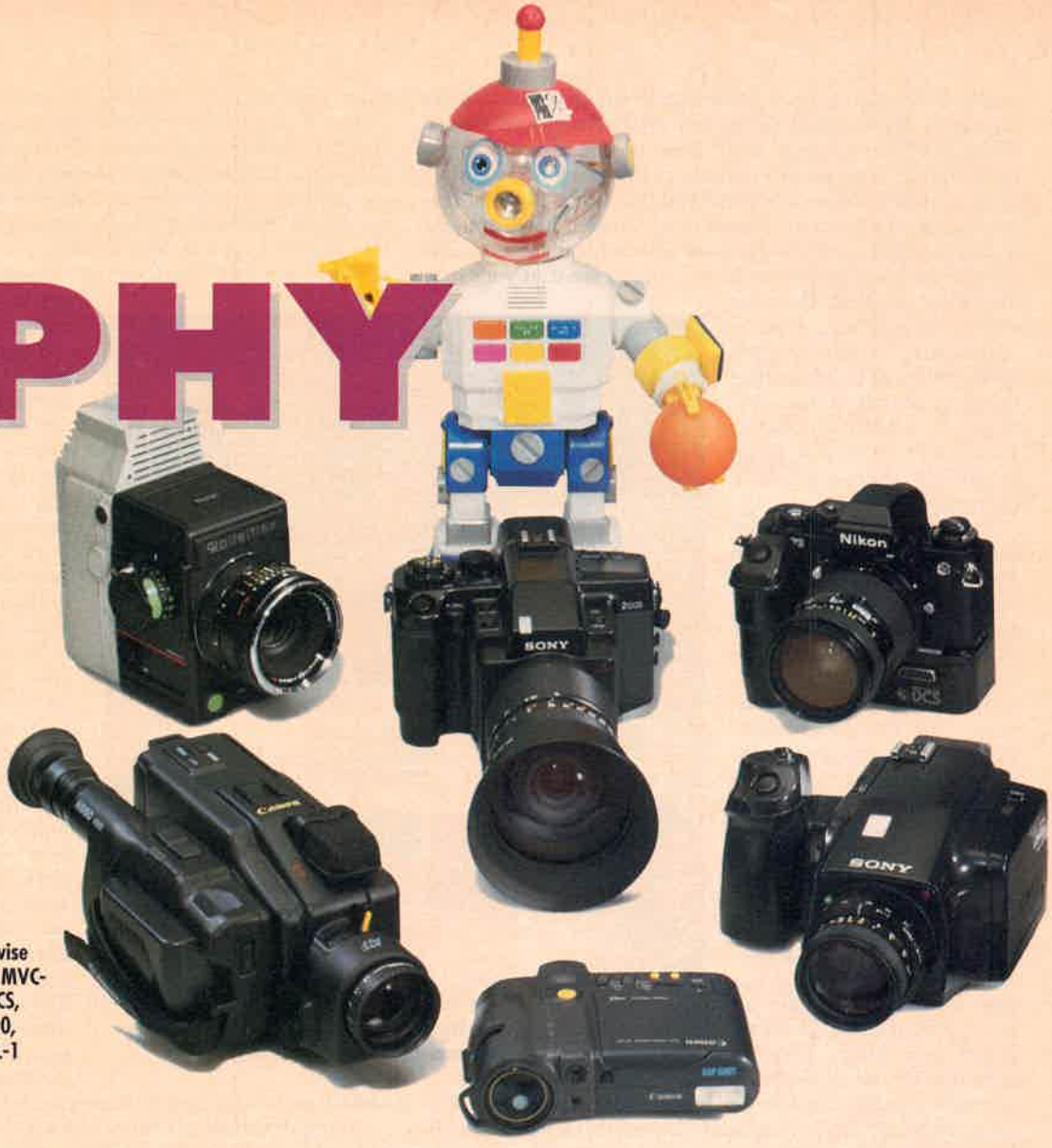


Digital groupies: Clockwise from top: Sony Mavica MVC-2000, Nikon/Kodak DCS, Sony Mavica MVC-5000, Canon RC-250, Canon L-1 video, Rollei Scanback.

PHOTOS BY KEN HANSEN PHOTOGRAPHIC

variety of interchangeable lenses, has a three-frames-per-second motor drive, and couples with a through-the-lens electronic flash. The major difference is that when you click the shutter the picture is stored, not onto a silver-based film emulsion, but on a tiny two-inch floppy disk.

To many, digital imaging means an orbiting telescope, CAT scan, or one of the many scientific or medical disciplines that use digital technology to produce a better view of our universe. Or you might think of Hollywood wizardry like the metamorphosing killer cyborg in *Terminator II* or the Coca-Cola advertisement in which a colorized Bogart, Cagney, and Louie Armstrong drop in on an Elton John party.

But digital imaging is increasingly being used by still photographers and graphic artists as well, albeit mostly on the professional level. That's because, at least for now, digital-imaging hardware and software is expensive and requires a fair degree of aptitude and skill.

According to Robert Schwarzbach, a member of the original group of instructors at Kodak's Center for Creative Imaging (CCI) in Camden, Maine, and a principal with ART-Lab, a San Francisco digital-imaging company that counts Apple Computer and Bugle Boy among its clients, most advertisements you see in magazines like *Vogue* or *Vanity Fair* have been digitally imaged in some way. "Advertisers want to make sure the images they are projecting to their audience have as much impact as possible. Every image you see has to have the perfect wave or tree, the prettiest dog or a perfect movement, a zit-free face. Trying to get all those elements with one click of the shutter isn't possible."

Kodak believes that film will be around for a long time to come—but it isn't betting the farm on it. Witness CCI, a teaching facility that Kodak established to introduce graphic arts and communications professionals to the rapidly expanding field of digital imaging. The center is something of a hedge, a working laboratory to spread the gospel of digital imaging while gauging its growing importance among professionals. As the theory goes, turn pros on to digital imaging, and eventually that enthusiasm may trickle down to the amateur market.

According to CCI director Ray DeMoulin, "Kodak realized that it had to be the world leader in digital as well as chemical imaging. If you think of it, railroads failed because they thought they were in the freight business, but they were really in the transportation business. Today, Kodak is in the film business but its ultimate goal is to be the world leader in imaging, whether it's chemical or digital."

As gene-splicing theoretically allows a geneticist to cross an elephant with an asparagus plant, digital imaging can be as wild and inventive as the artist's imagination. With a large palette of ultrasophisticated software tools, called paint programs, the user may combine or modify pictures and create images that don't or couldn't exist in nature.

For instance, it's a relatively easy matter to create a vi-

sually believable picture with digital imaging that shows an aging Elvis shaking hands with Amelia Earhart, Chicago's Sears Tower next door to the Empire State Building, or a miniature parachutist floating down onto a drop of water. When it's done skillfully with state-of-the-art equipment, even an expert would have a hard time determining that such images were electronically created, although common sense should tell your brain that your eyes are being deceived. Because digital imaging can produce surrealistic, bizarre, and yet fully believable photolike images, photographic evidence in tomorrow's courtroom may carry no more credibility than do today's polygraph results.

The basic technologies used in photography and digital imaging are quite different. Film-based photography consists of a number of chemical reactions to produce a print or transparency, while digital imaging involves capturing an image, uploading it into a computer, manipulating it, and finally outputting the finished picture. (The absence of chemicals has proponents calling it "environmentally correct imaging.")

The first step in digital imaging is to capture a photographic or electronic image. Most professionals involved in digital imaging shoot their initial pictures with film for two critical reasons: Film-based cameras are inherently cheaper than still-video cameras. Top professional 35mm film cameras like the Nikon F4s sell for about $2,000, while comparable still-video cameras like the Fujix DS-100 cost approximately $9,000. The other reason why film-based cameras are much more prevalent than still-video cameras is image quality. The coarsest-grained film has a much higher dynamic range—the sum total of resolution, contrast, tonality, and color fidelity that adds up to overall image quality—than the best still-video cameras.

For comparison, the toy robot was shot with a Nikon 8008 on Kodachrome 200 film. This is an enlargement of part of the transparency.

Why are still-video cameras so expensive, while at the same time the images they produce so inferior to film? The heart and soul of most video devices, whether they're still-video cameras, camcorders, or scanners, is the CCD, or charge coupled device. A CCD is a tiny 0.5-inch light-sensitive silicon chip. On each CCD are hundreds of thousands of sampling points, called pixels, that measure light intensity, color, and contrast. The more pixels, the better the dynamic range.

A typical amateur camcorder CCD has about 270,000 pixels, while a professional still-video camera may have a half-million or more. High-resolution CCDs are extremely difficult and very expensive to make. For instance, Kodak reports that it has a rejection rate of 95 out of every 100 CCDs manufactured for its DCS camera. The DCS has a 1.3 million-pixel CCD, the highest of any production-model still-video camera. But Kodachrome film has a silver granular structure resolution equivalent to 18 million pixels, which explains why film will probably be around for a long time, even if digital imaging becomes universally popular.

Just how good are still-video cameras? To find out, we arranged with Ken Hansen Photographic in New York City—one of the country's largest vendors of digital imaging products—to do a shoot, using six different devices, of a toy robot. The varying results appear with a description of the cameras on the facing page. For comparison, we include a straight (non-digital) enlargement of the robot made on Kodak Ektachrome 200 film.

Regardless of how the image is captured—film or still-video—it must be converted into digital data. All photographs and most video signals are composed of analog, rather than digital, data, consisting of continuously variable light, colors, and contrast. On the other hand, digital data exist in two states only—zeros and ones.

To understand the difference, think of a digital clock in which every second is marked by a change in a light-emitting-diode number. The observer receives no information about how much time passes between each second. An analog clock, however, has a second sweep, so it's possible to see an infinite, continuously variable representation of time between the seconds. This difference between analog and digital is critical because computers are strictly digital devices, so analog data must first be converted into digital data.

Generally, there are three types of devices used to convert analog images to digital data: digitizers, scanners, and frame grabbers.

All still-video cameras capture their images on analog CCDs. A digitizer must be used to convert those electrical impulses into digital pulses. Analog still-video cameras save their data on special two-inch analog floppy disks, which are then inserted into a shoebox-size external disk drive/digitizer for conversion. So-called digital cameras come equipped with built-in digitizers, but the same analog-to-digital conversion must take place.

Scanners are devices with a movable light and lens that pass over an image or object and reflect the light to a CCD, which then converts that visual information into zeros and ones. They vary greatly in size, shape, sophistication, and dynamic range. There are basically four types of scanners, ranging in price from $150 to $15,000: hand-held scanners—paintbrushlike devices that roll slowly over a photographic print or drawing; flatbed scanners—photocopylike machines for two-dimensional papers and prints; photo scanners—video cameralike boxes that digitize film transparencies or negatives; and array scanners—devices on copy stands that digitize three-dimensional objects.

Priced from $400 to $2,500, frame grabbers are peripheral boards that fit inside computers. They intercept video signals, whether from a VCR, a camcorder, or a TV set, and convert them into digital data.

Once the image is digitized, it is fed into a computer. It used to be that digital imaging required a mainframe or at

CANON RC-250

At $799, the RC-250—formerly known as the Xap Shot—is one of the least expensive still-video color cameras on the market. It's a fixed-focus, nonadjustable, low-resolution device that can save 50 images to a two-inch floppy and connect directly to a TV monitor for instant viewing. It features the lowest quality picture of any of the devices we tested, producing a fuzzy, slightly darkened image with a severe case of the jaggies. While designed primarily for amateurs, it's typically used for photo ID badges or newsletters where image quality is less important.

CANON L-1 VIDEO

We thought we would try a moderate-quality $2,400 camcorder with a $1,400 frame-grabber board, a fairly typical combination for users who require a relatively inexpensive way to scan in medium- or large-scale three-dimensional objects such as portraits, landscapes, and product shots. This camcorder/frame-grabber combination produces images that are marginally sharper than the RC-250, but the fine, yet very noticeable dark vertical lines characteristic of a captured TV signal make it unsuitable for quality reproduction.

SONY MAVICA MVC-2000

At $2,800, this is the lowest priced professional-quality still-video camera. Unlike the RC-250, the Sony features manual f-stop and shutter-speed capability, a zoom lens, and a much denser CCD. It captures and saves 25 images in the high-resolution mode or 50 in the medium-resolution mode. Even when set at medium resolution, the images produced are significantly sharper and brighter than the RC-250's. But at high resolution, it still lacks professional-quality definition and clarity. The MVC-2000 is suitable for low-resolution applications.

SONY MAVICA MVC-5000

The MVC-5000, at $10,000, is an all-professional device featuring two high-quality CCDs for greater resolution and dynamic range. It accepts interchangeable lenses, has TTL (through the lens) flash capability, and other features usually found on 35mm pro models. It's the still-video camera of choice by many news organizations because of its extensive support system in capturing, processing, and transmitting images on the spot. Resolution and dynamic range are virtually indistinguishable from film when the image is small.

NIKON/KODAK DCS

The $25,000 DCS is the first no-nonsense professional still-video camera. It combines an off-the-shelf Nikon F3 body and motor drive with Kodak's CCD back and a ten-pound pack containing a 200-megabyte hard-disk drive and digitizer to instantly process and save the images. The DCS is capable of capturing high-resolution images that approach the quality of film—it could reproduce the print on the robot's buttons—but the colors it renders are the most unrealistic of all the devices we tested. Also, the robot's hat and ball suffer from the jaggies.

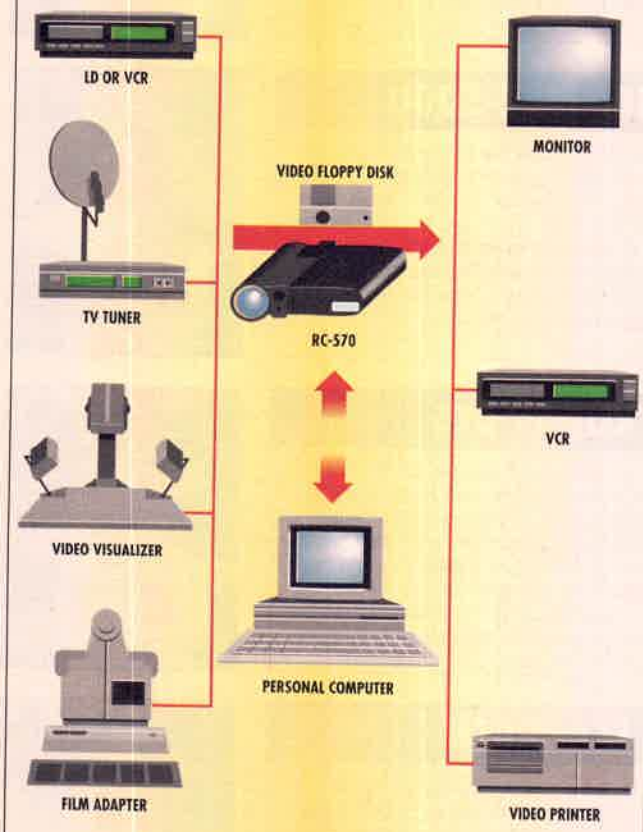
ROLLEI SCANBACK

Not strictly a camera, the Scanback is a miniature scanner that fits onto the back of a Rollei 6006. It produces magazine-quality images of great resolution and color fidelity, although the tiny scan lines mar an otherwise stellar performance. The Scanback, however, has two major limitations: One is that it cannot function in real-time because each scan takes approximately two minutes, limiting its usefulness to still-life photography and static three-dimensional scanning. The other encumbrance is price: It's $32,000, and that doesn't include camera or lens.

DOROTHY POTTER BARNETT

With a computer and a paint program, digital manipulation creates "impossible" images by taking electronic editing and enhancement down to the pixel level.

CANON'S DIGITAL IMAGING



A still-video camera like the Canon RC-570 can act as the heart of a digital system, scanning images from a variety of inputs onto a video floppy disk and then routing them as needed.

ELIOT BERGMAN

least a minicomputer. Now it's possible to produce professional-quality images on high-powered Macintoshes or IBM-PC-compatible systems equipped with top-of-the-line 68030 or 80486 central processing units, at least 32 megabytes of random-access memory, a 24- or 32-bit high-speed graphics board (capable of displaying 16.7 million different colors), a large RGB color monitor, and a hard-disk drive with at least 500 megabytes of storage (two- and three-gigabyte drives are common).

Why all the computing horsepower? For one thing, digital images consume inordinate amounts of hard-disk storage space, even when compressed. A single 35mm frame can consist of millions of pixels of basic image data. Then, depending upon the dynamic range, each pixel will also be accompanied by 8, 16, 24, or 32 bits of data, containing additional information such as color, hue, intensity, and shading. A single low-resolution eight-bit image from a scanned-in 35mm transparency takes up, on average, 700 kilobytes of disk space, which means that one 36-exposure roll will consume more than 25 megabytes. A single image scanned in at the highest resolution in the 32-bit mode, however, can occupy more than 80 megabytes.

Another reason for using a fast, high-powered computer system is that displaying, editing, and redrawing large graphics files can be very time-consuming. Actually, it's possible to do professional-quality digital imaging on less powerful systems, but because of the speed and storage requirements it isn't very practical.

To illustrate just what can be involved in this kind of process, consider this case history: Last November, Gregory Heisler received the sort of assignment that most photographers would kill for—photograph TV mogul Ted Turner for the cover of *Time* magazine's 1991 Man of the Year issue. Challenged to create an artistic metaphor about the man who established CNN, the world's largest electronic journalism organization, Heisler decided to produce not a photograph, but to use computer technology for *Time*'s first-ever digitally imaged cover.

Like most professional photographers, Heisler had known very little about computers and even less about digi-

[*Continued on page 92*]

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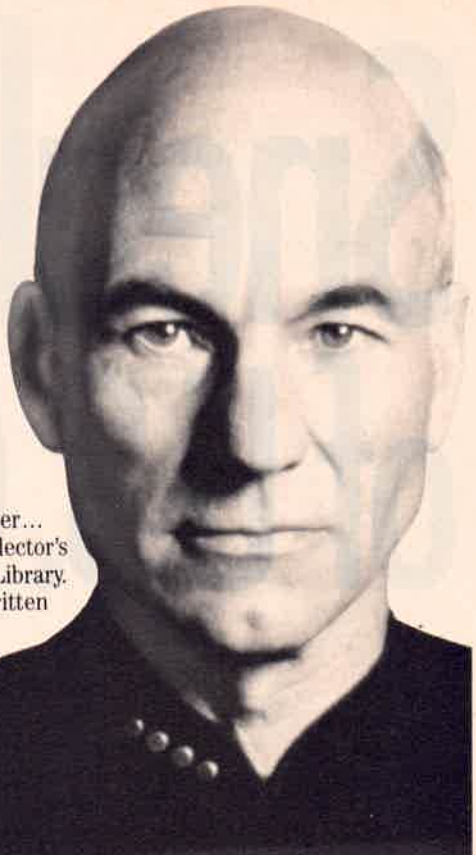

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A Five-Year Guide

Sneak Previews of U.S. Cars to Come

With Detroit's 1993 model year snapping clearly into focus, it's the cars that are several years further down the road that are beginning to define our automotive future.

1995 Ford Taurus

The styling of the next-generation Taurus, due in 1995, promises a lower, wedgelike hoodline compared with the present car (above right).

KGP PHOTOGRAPHY

KGP PHOTOGRAPHY

Front and rear styling updates for the T-bird, as well as a modular V8, arrive next year.

KGP PHOTOGRAPHY

By popular demand, a Mustang revamp will retain rear-drive and add muscle with a 300-hp V8.

STOP PRESS

Development mule for the Sundance/Shadow replacement underscores the new style at Chrysler.

KGP PHOTOGRAPHY

Ford will add a minivan based on the Taurus running gear, yet keep the Aerostar in its line.

HIDDEN IMAGE

All new and boldly styled, Lincoln's personal coupe will debut with a 32-valve V8.

Stand too close to the forest, the old saying goes, and you'll certainly lose sight of the trees. So it is, too, in the automotive universe: Try to absorb the whole picture of future-model programs in one take and you'll never be able to grasp the industry's general direction. Back up a few steps with us, though, limit your view to a few key parts at a time, and it begins to fall into order.

As we head into the heart of the '90s, there is every indication that the pace of technological change in the American automobile industry continues to quicken as competition intensifies. Well-defined trends are emerging: American manufacturers have relearned how to work quickly and get things done right the first time. Recent reports show that the manufacturing cost of the average domestic small car is lower than that of the average Japanese small car produced in Japan. Individual machines, workers, and plants are increasingly more efficient in the American auto industry, and the cars to come are going to be significantly better and sturdier because of the new ways in which they are designed and manufactured.

Ford

Model	1993	1994	1995
Ford			
Festiva (BT17)		All-new, convertible added	Turbo 1.5L engine option
Escort (CT20)	Face-lift, new colors, moldings		
Probe (ST44)	All-new coupe with 2.5L V6		
Tempo (CDW27)		All-new with 1.8L I4 and V6	
Mustang (SN95)	Cobra limited-edition arrives	All-new Mustang, 300-hp V8	Possible 24-valve V8 engine
Thunderbird (MN12)		Front/rear face-lift with modular V8	
Taurus (DN5)	SHO gets automatic transaxle		New Taurus, 2.5L V6, 4.0L V8
Crown Victoria (EN53)		Minor cosmetic update	
Aerostar (EN53)		RWD Aerostar replacement	Taurus-based van added
Lincoln-Mercury			
Capri (SA30)			
Tracer (CT20)	Face-lift, light-bar grilles	Re-skinned Tracer	
Topaz (CDW27)		All-new with Zeta 4 and V6	
Cougar (MN12)		Face-lift, modular engine	Possible ASC convertible
Sable (DN5)			All-new Sable 4.0L V8
Grand Marquis (EN53)		Minor cosmetic changes	
Villager (VX54)	New Ford/Nissan minivan		
Mark VIII (FN10)	Debuts with 32-valve V8		Convertible version likely
Continental (FN9)			All-new, front-wheel-drive 4.0L V8
Town Car (FN36)		Front/rear redesign	

Chrysler

Model	1993	1994	1995
Chrysler-Plymouth			
Colt (B1)	New Mitsubishi-based B2		
Sundance (P)		Replaced by all-new PL series	
Laser (BD)		New Diamond-Star car debuts	
Acclaim (A)			New car (JA) debuts
Voyager (S)			New minivan, new 2.5L I4
Concorde (LH)	All-new car with 3.3L V6		
LeBaron (J)	Front-end face-lift	New Mitsubishi-based LeBaron	New LeBaron coupe, 2.0L I4
New Yorker (C)		Long-wheelbase LH body debuts	
Fifth Avenue (C)	Replaced by LH series		
Imperial (Y)		Replaced by New Yorker LH	
Town & Country (S)			New minivan, new 2.5L I4
Dodge			
Colt (B1)		New Mitsubishi-based B2	
Shadow (P)		Replaced by all-new PL series	3-cylinder 2-stroke engine
Daytona (G)		New Mitsubishi-based Daytona	New Daytona coupe, 2.0L I4
Spirit (A)	Soft-nose face-lift		
Intrepid (LH)	All-new car with 3.3L V6		Performance coupe debuts
Dynasty (C)	Replaced by LH series		
Stealth (R)			
Viper		Chrysler 300 4-door Viper	
Caravan (S)			New minivan, new 2.5L I4
Eagle			
Summit (B1)	New Mitsubishi-based B2		
Talon (PJ)		All-new Talon by Diamond-Star	
Vision (LH)	All-new car with 3.3L V6		4WD-version added

Letter/number designations in parentheses indicate the platform family on which a model is based. Use this to determine corporate twins built on common platforms (such as the Ford Thunderbird and Mercury Cougar). For the purposes of this chart, U.S. cars are defined as recognized American nameplates, regardless of manufacturing location or percentage of local content.

The Toronado coupe (and its Riviera sibling) have failed to score for the GM team, so a new game plan has been adopted—a fresh-from-the-tires-up four-door sedan for next year in search of a larger market volume.

1994 Oldsmobile Trofeo

HIDDEN IMAGE

1994 Dodge Ram Van

STOP PRESS

Dodge's rear-drive heavy hauler takes on a fresh look, benefiting from truck updates.

1994 Chrysler New Yorker

Stretched version of the LH platform gets a unique greenhouse profile and the full luxury treatment.

1994 GM Full Size

HIDDEN IMAGE

This prototype front end on an existing GM platform reveals the upcoming Buick or Olds styling exercise.

1994 Chevrolet Monte Carlo

A sleek coupe based on this show car will be added to the Lumina line next year.

1995 Chevrolet Lumina APV

Shifting more mainstream, APV's long aero-nose will be bobbed like the Sizigi concept vehicle.

ON THE HORIZON: DODGE'S V10

In the utilitarian world of trucks, fashion and technology march forward at a decidedly slower pace. Still, the segment is so profitable that the burst of activity slated in coming model years comes as little surprise.

The greatest buzz surrounds the 1994 release of Dodge's revamped line of full-size work trucks known as the T300 series. While styling of the prototypes spotted around Detroit reflects the American upright tradition, we expect great leaps in ride and refinement, much as the way the Pentastar team has accomplished with the Grand Cherokee. The top power-train option will be an iron-block V10 based on the 488-cubic-inch Viper motor.

Compact pickups from Chevy and Ford are both slated for sheetmetal freshening. Ranger gets reworked for '93, while the S10 revamp is perhaps two years away. Chrysler's Grand Cherokee will spawn an upscale Grand Wagoneer in '93, with a 5.2-liter V8 delivering power. The present XJ-based Cherokee line, meanwhile, shifts to an entry-level positioning.

1995 Chevrolet S-10 Pickup

STOP PRESS

1994 Dodge Ram Pickup

KGP PHOTOGRAPHY

Just as apparent, there will be fewer, better equipped models to choose from as the Big Three weed out slow-movers and continue to streamline operations. Most certain among these moves is an expected consolidation of Chrysler sales outlets, which means the demise of either the Plymouth or Eagle brand. A similar move could come at General Motors in an attempt to eliminate redundancy in the marketing efforts of Buick, Oldsmobile, and Pontiac. The timing of such moves, of course, will be governed by economic conditions in the months to come.

With the advent of "modular" engines, chassis, and power-train designs, and ever more capable CAD/CAM design systems, the product cycle times of the American manufacturers are shortening, not quite yet to the frenzied schedules of the Japanese, but are much faster than five years ago. The best example so far of that progress is the simple-but-effective Dodge Viper R/T 10 roadster, which took only 36 months to go from concept car to production car under the platform team development method—a record the others are trying to emulate with more complex sedan designs. This limited-production model also portends a new trend in manufacturing for ever-smaller niches as highly flexible production systems become more feasible.

The U.S. auto makers are beginning to see the realization of the cab-forward look, first tested for public reaction on the auto show circuit and now moving into the mass market. In fact, our chart and photos indicate that this look may well begin to dominate new-car design, with the arrivals this year of the Mazda 626 and MX-6, Ford Probe, and the Chrysler LH sedan trio—the Chrysler Concorde, Dodge Intrepid, and Eagle Vision. Cab-forward design emphasizes short front fenders, very rounded shapes, short overhangs, and large expanses of glass—a profile that will get us into the next century ahead of time.

Cab-forward designs will share the roads in the mid-'90s with the next generation of aero-minivans like the Mercury Villager/Nissan Quest pair debuting for 1993, and the Ford Taurus-based minivan due in 1995. Significantly, the spy photos and allar to cars have caught on strongest; the aero-nose offerings of GM's APV trio languish by comparison, awaiting restyling or a shift in buyer sentiment. The minivan market is expected to top one million vehicles per year starting in 1993, and there will be a whole new round of redesigned mini- and full-size pickups as America's appetite for personal-use trucks continues to grow.

In the mid '90s, we will be in the earliest stages of the alternate-fuel and

General Motors

Model	1993	1994	1995
Buick			
Skylark (N)			Possible cancellation
Century (A)			
Regal (W)		Sheet metal face-lift	Possible cancellation
LeSabre (H)		Possible new 4.0L SOHC V8	
Park Avenue (C)			Face-lift
Roadmaster (B)		Possible new 4.0L SOHC V8	
Riviera (E)		Larger new Riviera	
Cadillac			
Seville (K)	Northstar 32-valve V8		
Eldorado (E)	Northstar 32-valve V8		
DeVille (C)		All-new on Seville chassis	
Fleetwood (C)		All-new on Seville chassis	
Brougham (B)	All-new, largest U.S. sedan		
Allanté (V)	32-valve V8, active suspension		
Chevrolet			
Cavalier (J)			Possible cancellation
Corsica/ Beretta (L)		New car on JLN platform	
Lumina (W)		Monte Carlo coupe & face-lift	
Caprice (B)	New rear-half restyling	Major rebody, new SOHC V8	Possible cancellation
Camaro (F)	All-new Camaro rear-drive		
Corvette (Y)	More power for ZR-1	Callaway LT-1 derivative	
Lumina APV (U)	Moderate face-lift, air bags		New steel body, new chassis

Model	1993	1994	1995
Geo			
Metro (M)			
Prizm (S)	New Corolla-based Prizm		
Storm (R)			All-new Isuzu-based coupe
Impact			
Coupe		2-seat electric for California	
Oldsmobile			
Achieva (N)	New model		
Ciera (A)			Possible chassis consolidation
Cutlass Supreme (W)		Replaced by all-new Anthem	
Eighty-Eight (H)		Possible new 4.0L SOHC V8	Redesign
Ninety-Eight (C)			
Toronado (E)	Production ends on Toronado	All-new 4-door Trofeo sedan	
Silhouette (U)	Moderate face-lift		New steel body, new chassis
Pontiac			
LeMans (T)			Daewoo car dropped from line
Sunbird (J)			
Grand Am (N)		Possible 3.4L V6 GTO version	
Grand Prix (W)			Under review
Bonneville (H)		Possible new 4.0L SOHC V8	
Firebird (F)	All-new Firebird coupe		
Trans Sport (U)	Moderate face-lift		New chassis
Saturn			
SL1 (Z)			
SL2 (Z)	Luxury version added		
SC1	Low-cost coupe		

Letter/number designations in parentheses indicate the platform family on which a model is based. Use this to determine corporate

FIVE YEARS DOWN THE ROAD

Viewed from our perspective on the eve of the 1993 selling season, most of Detroit's known far-future programs seem to consist of straightforward revamps and product line consolidations that have been pushed back from the middle of the decade as cost-cutting measures. In reality, the prospects are not quite so grim because recent (and dramatic) cuts in the gestation period of new cars promise a timely release of vehicles at a pace nearly equal to Japan's.

With the era of chiseled-in-stone long-range product planning rapidly giving way to fast-track engineering methods, Detroit's Big Three (and we assume that will still mean General Motors, Ford, and Chrysler in the late 1990s) have gained far more flexibility in their ability to respond to market conditions. So it is entirely plausible that cars not even under consideration today could be on the road in 1996. Late in the '90s, Detroit will certainly deliver responses to the legislation already in force today. Electrics, hybrids, and ultra-low-emission vehicles will arrive to meet California mandates, with particular emphasis on high-efficiency alternate-fuel-powered piston engines. We don't expect these vehicles as a response to market demand or oil prices, but primarily as a function of air quality rulings.

Traditional large cars, always among the slowest to evolve, are slated for redo in the next five years, this time around with new platforms to accompany the updated skin. Ford's next-generation Crown Victoria and Grand Marquis will arrive by '97, remaining at six-passenger dimensions. The Lincoln Town Car will be redone a year earlier, likely staying with a body-on-frame design to accommodate stretching for the limousine market.

GM's large front-drive sedans—the H and C platforms—are up for renewal in the 1996 time frame too. Given the General's recent penchant for product-line surgery, it's likely that some of the slower-moving nameplates will fade away in this move, while the survivors will benefit from the smooth power delivery of a small displacement V8 based on Cadillac's trusty 4.9-liter engine. The fast-growing Saturn franchise will logically need fresh hardware to sustain growth, so expect this division to move up into the midsize battleground with larger platforms and its own V6 power plants. Two of GM's more evocative offerings, the Cadillac Allanté and Chevrolet Corvette, are both penciled in for makeovers in the mid '90s.

electric zero-pollution vehicle programs mandated in California. These programs, implemented in the country's biggest single car market, will tell the rest of the country what will work in the real world and what won't. In the labs of greater Detroit, the level of research activity on these projects is very high; there couldn't be a better time for the great battery breakthrough than right now. California buyers can already select from a good, solid menu of flexible-fuel and alternative-fuel sedans and vans, and the offspring of GM's Impact program (quite possibly with a different brand designation) is slated for introduction less than two years from now.

In addition to environmental issues, the Big Three must confront the costs and complications of new federal side-impact protection requirements due in 1994, as well as the orderly transfer of federal passenger-car safety requirements to pickup trucks, minivans, and sport utility vehicles, starting in 1994 and being phased in through 1997. While that proceeds, the demand for left- and right-side front air bags, three-point seat belts for all seating positions, and ABS traction-control systems continues to rise, as consumers become more and more aware of the safety benefits.

The mid '90s are likely to see rapid expansion of technologies, such as electrically heated catalytic converters to meet California emissions rules, and variable valve timing, which enables the buyer to have two engines in one: a low-speed, high-economy engine for everyday use, and a high-revving, high-performance engine on demand. There are a number of new two- to three-liter V6 engines with four-valve combustion chambers expected to appear in upcoming products too, as new-engine families begin to arrive.

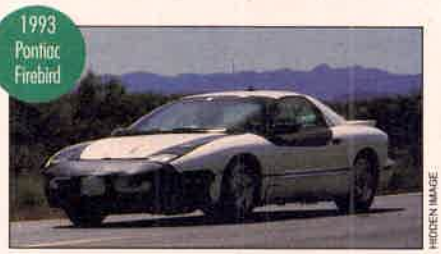
Over the next few years, electronic control systems in both cars and light trucks will be integrated into a single, massively powerful power-train-control computer to maximize fuel economy, performance, and reduce emissions while simultaneously managing ABS, traction control, adjustable active or passive suspension, four-wheel-drive systems, and all-wheel steering. A second main computer will manage the rest of the vehicle's electrical or electronic functions, including climate control and ergonomic, navigational, and entertainment systems.

In addition to this whole new generation of engines with four-valve heads and high-IQ computers, Chrysler's large-displacement two-stroke engine and the Orbital two-stroke engine, which is under license to most major manufacturers, may appear before long in the gasoline-engine category, itself alive with 300-horsepower examples.

And in 1993, the Big Three will continue to try to get closer to the Japanese in price, quality, and customer satisfaction by offering increasingly better-informed buyers the performance and features they want in their vehicles, their service, and their financing/insurance packages. Cheap, simple leasing programs are already being tried on a large scale by GM, Ford, and Chrysler, along with simplified pricing, all-inclusive option packages, and generally longer, no-deductible warranties to attract customers back into the traditional domestic-brand showrooms. Next month, we

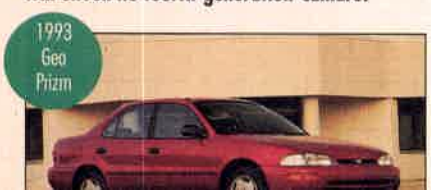
HIDDEN IMAGE

Still rear-drive and still V8-powered, Chevrolet will unveil its fourth-generation Camaro.



HIDDEN IMAGE

Steel and composite panels keep weight under control for Pontiac's matured pony car.



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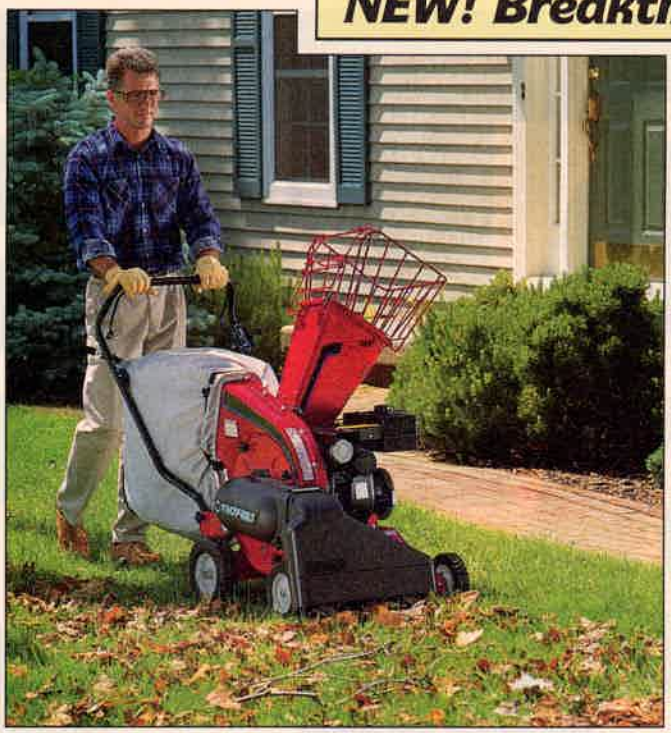

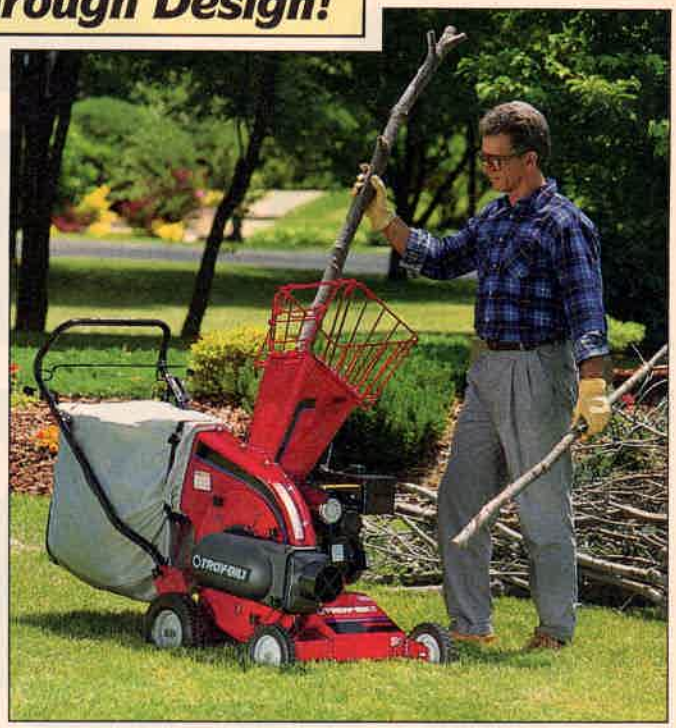

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ASTE WATC

Every million years or so an asteroid impact wreaks havoc on Earth. Astronomers now propose a global telescope network as an early warning system.

BY ROBERT LANGRETH

At 10:25 p.m. on Jan. 18, 1991, a long, faint streak appeared on computer images produced by a telescope atop Kitt Peak, Ariz. The streak represented a small asteroid, about 30 feet in diameter, moving toward Earth at 20,000 mph.

Twelve hours after it was first sighted, it missed the planet by a little more than 100,000 miles—less than the distance to the moon. If it had hit Earth, the force of impact would have been greater than the atomic blast that devastated the Japanese city of Hiroshima.

For University of Arizona astronomer Tom Gehrels, this event was just another small reminder of the dangers that lurk not far outside Earth's atmosphere. For the last several years, Gehrels has been the head scientist for Spacewatch, the world's most advanced telescope for detecting asteroids and other small objects in the solar system. It was one of his post-doctoral students who observed the Jan. 18 near-miss.

Most asteroids—hunks of rock or metal—orbit the sun harmlessly in a belt between Mars and Jupiter, Gehrels explains. A significant number have orbits, however, that bring them zipping across the path of Earth. Every once in a while one of these so-called Earth-crossing asteroids actually scores a direct hit. Says Gehrels: "I've been warning people about this [danger] for 20 years."

Lately, his efforts seem to be paying off. In a recent report to Congress, an international panel of astronomers (including Gehrels) estimated that there are roughly 2,100 Earth-crossing asteroids larger than 0.6 miles in width orbiting the sun, and scores of smaller ones. Approximately once every half-million to a million years, says the NASA-sponsored committee, one of these monster-size objects smashes into Earth, with a force great enough to kill most life on the planet.

It's not as if it hasn't happened before. Sixty-five million years ago, most researchers believe an asteroid several miles wide slammed into Earth, sending a thick cloud of dust and debris around the globe. Deprived of sunlight, 60 percent of the plant species and 90 percent of the animal species on the planet were wiped out—probably including the dinosaurs. In addition to this catastrophe, scientists have identified the remnants of about 130 other collisions, in the form of impact craters scattered across Earth.

Clark Chapman, a committee member from the Planetary Science Institute in Tucson, Ariz., sums up the situation by saying: "The Earth is like a target in space."

In deciding how significant the threat is, and what, if any, action should be taken, much is made of the statistical chances of such a calamity occurring. During your lifetime, say panel members, the odds are roughly the same that you could be killed in an airplane crash as by an asteroid: about 1 in 7,000. There's one important difference, though. In the case of the larger asteroids, it's as if the whole population of Earth were riding on one jumbo jet. In short, it only takes one very large asteroid to put an end to the statistical quibbling.

Up until now, the world's asteroid watchers—approximately a dozen full-time scientists—have found and computed the orbits of about 150 nearby objects, most of them within the last decade. At this rate it will

ROID HERS

Waiting till dark: Once the sun sets, University of Arizona planetary scientist Tom Gehrels will get down to the business of asteroid-hunting at the Kitt Peak Spacewatch Observatory (background).

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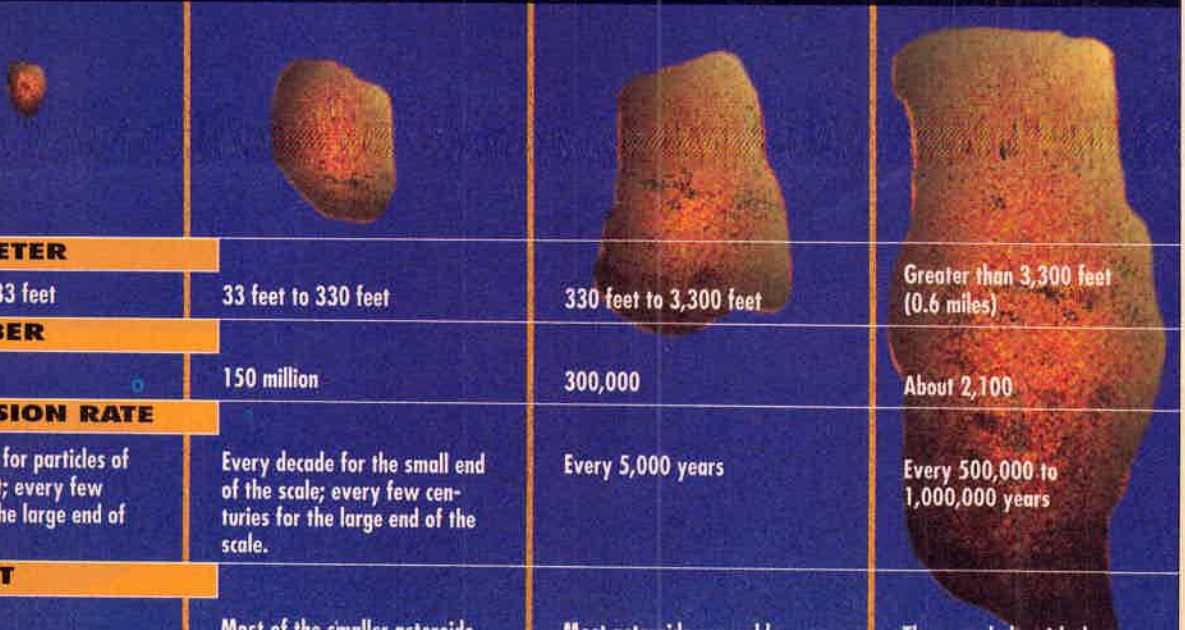
EARTH-CROSSING ASTEROIDS AND COMETS



DIAMETER			
Less than 33 feet	33 feet to 330 feet	330 feet to 3,300 feet	Greater than 3,300 feet (0.6 miles)
NUMBER			
Billions	150 million	300,000	About 2,100
COLLISION RATE			
Constantly for particles of cosmic dust; every few years for the large end of the scale.	Every decade for the small end of the scale; every few centuries for the large end of the scale.	Every 5,000 years	Every 500,000 to 1,000,000 years
RESULT			
These are so small that the vast majority burn up harmlessly in the upper atmosphere as they decelerate. Nevertheless, a few of the harder metallic meteors do reach Earth's surface, and there are recorded instances of humans being injured by pebble-size fragments of larger objects.	Most of the smaller asteroids in this size range burn up high in the atmosphere, so that no damage occurs on the ground. The larger-size ones tend to disintegrate closer to the ground. If one comes near or reaches the ground, the effect is similar to the explosion of dozens of nuclear warheads detonated at altitude or on impact. In 1908, a 200-foot-wide celestial body exploded over the Tunguska region of Siberia, flattening trees across an 800-square-mile area.	Most asteroids several hundred feet wide reach the ground intact, producing a crater 1.2 miles or more in diameter and exploding with a force equal to hundreds or thousands of nuclear weapons. At the upper end of this scale, the resultant shock wave, fires, and debris could obliterate whole states or even countries.	These explode with the energy of millions of atomic bombs and leave a crater 10 to 15 times wider than their own diameter. Anything larger than a mile in diameter can eject enough dust into the atmosphere to block light around the globe —killing most animal and plant life. Sixty-five million years ago, many scientists believe, dinosaurs and other life-forms were killed by the impact of an asteroid several miles wide.

(All figures in this table are approximate.)

SOURCE: NASA NEAR-EARTH-OBJECT DETECTION WORKSHOP

take centuries to chart the majority of near-Earth asteroids.

The NASA panel proposes a network of six semiautomated asteroid telescopes scattered across the world to detect asteroids at a much faster pace. By using advanced photon detectors (based on those in Spacewatch) and larger mirrors than existing asteroid telescopes, the network could locate, within 25 years, approximately 90 percent of the near-Earth asteroids large enough to cause global upheaval. Since most asteroids approach Earth gradually as their orbits close on the planet, there could be decades of warning time.

Determining a "search strategy" for celestial objects involved a tradeoff, say panel members. "You can observe a large area of sky quickly, but then you can't peer so deep into space, because you are scanning the sky too fast," explains Edward Bowell, a planetary scientist at the Lowell Observatory in Flagstaff, Ariz. "Or you can concentrate on a smaller area of sky and observe fainter objects" [ones that are farther away, for example], but then you will miss many asteroids orbiting outside that small region.

Balancing these competing objectives, the committee recommends scanning about one-seventh of the entire sky each month. To cover this area (and to ensure that the asteroid survey isn't incapacitated by bad weather in one region), three widely spaced telescopes in each hemisphere are required. This approach would allow the telescopes to detect large asteroids as far away as Mars or Jupiter. Over the 25-year time period, the search would cover the whole sky repeatedly, giving scientists multiple chances to detect most nearby asteroids.

The price of the worldwide network would be $50 million for construction, plus $10 million to $15 million a year for operation—a modest cost, according to proponents. "One way to think of this is as an insurance policy against a very unlikely but catastrophic event," says committee chairman David Morrison, a planetary scientist at NASA's Ames Research Center in California. "At issue is the survival of civilization. That's surely something that matters enough to us that if we can carry out a survey it's prudent to do so."

Astronomers have long recognized that heavenly objects hit Earth. As early as 1902, scientists explored the aptly named Meteor Crater, a $^{3}/_{4}$-mile-wide depression produced when a small iron asteroid crashed into the northern Arizona desert some 50,000 years ago.

And in 1908, a celestial object composed of more fragile materials—and perhaps 200 feet across—disintegrated in the air over the Tunguska region of Siberia. The resultant atmospheric shock wave, equivalent to the explosion of several nuclear warheads, flattened almost 800 square miles of uninhabited forest.

Only recently, though, have scientists realized that as-

teroid impacts have influenced the evolution of life. In 1980, Nobel Prize-winning physicist Luis Alvarez first published his theory that the extinction of the dinosaurs stemmed from the impact of an enormous meteorite ["Science Newsfront," Nov. '91]. In the following years, geophysicists unearthed increasing chemical evidence for such a cataclysm from Earth's own strata.

Many now believe they have located the site of this crash: a 120-mile-wide crater hidden in strata beneath the Yucatán peninsula in Mexico. Furthermore, this trail of evidence has provided the starting point for a more all-encompassing theory—that meteor collisions account for the mass extinctions that have occurred roughly every 30 million years during Earth's history. "We owe our existence to [the dinosaur] cataclysm," writes Robert Park, a physicist at the University of Maryland, in a recent *New York Times* editorial.

Alvarez's theory also renewed interest in locating asteroids and comets in space. In the 1980s, astronomers at separate institutions began two limited-scale search efforts, which are still in operation: the Mount Palomar Asteroid and Comet Survey in California and Spacewatch (see Night Shift at Kitt Peak). These complemented the first long-term asteroid survey, also at Mount Palomar, which began in 1973.

Besides the January 1991 near-miss, seen by Spacewatch, other astronomers discovered that an orbiting boulder the size of an aircraft carrier had sailed within 400,000 miles of Earth in March 1989. They only discovered it, however, long after it missed Earth.

In 1990, Morrison of NASA briefed the House of Representatives' Science Committee on his view of the meteor hazard. The same year the American Institute of Aeronautics and Astronautics released a position paper calling for an expanded effort to detect these orbiting hunks of rock. At the request of the House panel, NASA then convened two groups: Morrison's committee, charged with developing a comprehensive search strategy, and a second, charged with identifying ways of deflecting them.

In many respects, an asteroid or comet collision is similar to the detonation of a nuclear weapon, minus the radioactive fallout. Imagine a rock several hundred yards long, with a mass of billions of tons, speeding through space toward the planet at

[*Continued on page 80*]

NIGHT SHIFT AT KITT PEAK

Atop Kitt Peak in the desert outside of Tucson, Ariz., a prototype for the NASA panel's asteroid search already exists: Astronomer Tom Gehrels' Spacewatch telescope. It aims at making a database of asteroids, comets, and any other small objects it discovers. To see this telescope in action, POPULAR SCIENCE visited it one night last May.

At 5:00 p.m. in a windy parking lot at the summit, I meet Tom Gehrels, who is manning the telescope this night. We walk toward the 30-foot-high dome that houses Spacewatch—one of more than a dozen observatories at Kitt Peak.

The two hours before dark are devoted to preparation for the night: determining the directions to aim the telescope and then focusing the mirrors. In addition to peering at several regions Spacewatch has not examined yet, Gehrels also plans to reobserve a couple of objects first located the week before. Once an asteroid has been sighted several times, Gehrels and his colleagues can calculate its orbit decades into the future.

Spacewatch contains a strange juxtaposition of old and new. Propped up by a splintering broomstick ("We use what works"), a metal container on the side of the telescope holds the world's most advanced device for imaging light. Rather than taking photographs, this device converts photons received by the telescope into a grid of electronic charges, which are loaded directly onto a computer workstation. The method is much more sensitive to faint objects like comets than traditional photography.

The telescope itself dates from 1920. Although its 36-inch mirror is small by modern standards, it still can locate about two Earth-crossing asteroids per month, plus more than two thousand more distant asteroids residing in the main belt between Mars and Jupiter. At this rate, it will take centuries to chart the majority of near-Earth asteroids.

Once the sun sets, Gehrels gets down to business. Traditionally, astronomers have been depicted as standing under the open sky watching the stars through an eyepiece of a giant telescope. Not anymore. Gehrels sits in a small office beneath the telescope in front of a high-resolution computer monitor. Every ten seconds or so, a new field of stars flashes on the screen. The computer automatically checks for the faint smears or trails that usually represent fast-moving objects like comets. It sometimes misses objects, however, so Gehrels must also scrutinize the monitor himself. Although not as romantic as the popular image, his work is still exciting: At any moment he may stumble upon something that's never been seen before.

By 9:30 the telescope has seen more than ten new asteroids. All of them, though, are in the main asteroid belt and will never pose a threat to Earth. Now Gehrels is hunting for a much closer visitor, a small object nearly the same distance to the sun as Earth, although its orbit is tilted at a different angle. "We first saw it a week ago. It's very fast moving . . . [perhaps part of an] entirely new class of objects," Gehrels bubbles. In several minutes, he finds it: a long, nearly invisible blur at the edge of the screen.

An hour and a half later, clouds begin rolling in—an unusual sight in the Arizona desert. Within a few minutes, they partially obscure the view, and Gehrels only expects things to get worse. In case it clears up, however, he must stay the rest of the night.

The final tally for the evening: several hundred new main-belt asteroids, two unidentified objects close to Earth, but nothing on a collision course. If there are any looming killers out there, Spacewatch hasn't found them tonight.—*R. L.*

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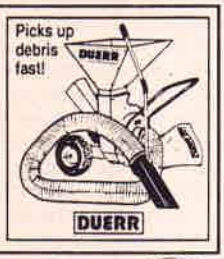

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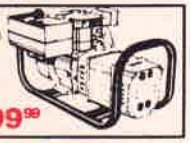

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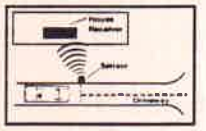

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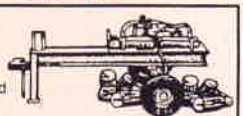

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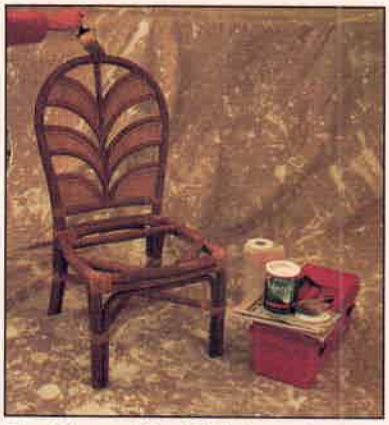
Minwax Company, leading manufacturer of fine wood finishing and wood care products for almost 90 years, introduces Polycrylic™ Protective Finish: a beautifully clear and durable topcoat that cleans up in minutes with plain water. Fast-drying, with minimal odor and a non-yellowing formulation, Polycrylic is so easy to apply that you'll get the same high-quality results, whether you're a novice or a seasoned do-it-yourselfer.

Use the new topcoat on any interior wood surface, either stained or unstained; it's ideal for projects like staining kitchen cabinets, finishing unfinished furniture for baby's nursery, adding decorative moldings or refinishing hardwood floors. Thanks to Polycrylic's crystal clear, non-yellowing formulation, it works especially well over light woods like maple and ash.



Two Minwax Wood Finishes -- dark Special Walnut and lighter Fruitwood -- and a topcoat of Minwax Polycrylic give this chair a bright new look.

Its unique formula makes Polycrylic the convenient alternative to traditional topcoats. The product is non-flammable and easy to apply, even in adverse conditions such as low temperatures or high humidity. Because it has little odor, it requires less ventilation than traditional topcoats. That means you can work indoors comfortably on projects all year round. The topcoat dries to the touch in just 30 minutes, allowing you to complete large projects faster than with traditional topcoats.

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MINWAX®

Asteroids

[*Continued from page 79*]

45,000 mph—a typical speed for a meteor. When such an object hits the ground and slams to a halt, all the energy contained in its combination of speed and mass (kinetic energy) is released. Some of this energy creates an atmospheric shock wave, which radiates outward for many miles. Another portion turns into heat, producing an enormous fireball. The rest is absorbed by Earth, yielding a crater 10 to 15 times the size of the meteor itself and ejecting dirt into the atmosphere.

Although asteroids vary in size from a few inches to a few miles, the large ones pose the biggest danger, even though there are far fewer of them (see Earth-Crossing Asteroids and Comets). At some point between 0.3 and 3 miles in diameter, a meteorite becomes large enough to produce a global catastrophe, no matter where it actually touches down. (This uncertainty stems from the fact that scientists don't fully understand the physical and chemical effects of such a large explosion.)

The total amount of energy released by a collision with a 0.6-mile-wide meteorite, for example, would equal a million times that of the Hiroshima blast, says Gehrels. "You don't need any scientific training to know that when you have an amount of energy this great that something very, very drastic is going to happen."

An asteroid apocalypse

Although its projections are based on computer models of nuclear winters—among the most dicey of scientific studies—the asteroid detection panel offers a likely scenario for such a cataclysm: "Dust thrown up from the crater would lead to total darkness over the whole Earth, which might persist for several months. Temperatures could drop as much as tens of degrees Celsius. Nitric acid produced by the burning of atmospheric nitrogen in the impact fireball would acidify lakes, soils, streams, and perhaps the surface layer of the ocean. Months later . . . water vapor and carbon dioxide released into the atmosphere . . . would produce an enhanced greenhouse effect, possibly raising global temperatures by as much as 10°C above preexisting ambient temperatures."

The temperature swings, darkness, and chemical disruption would decimate world agriculture, resulting in mass starvation for both humans and animals. "All of society as we know it would be destroyed," says Gehrels.

What to do if such an asteroid is spotted was the subject of the second, more contentious NASA workshop at Los Alamos National Laboratory in

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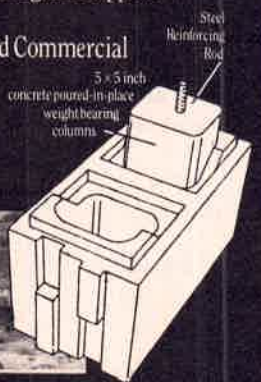

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Asteroids

[Continued from page 80]

New Mexico. Consisting mostly of nuclear physicists, the 1991 gathering quickly turned into a "revival meeting for Strategic Defense Initiative true believers," writes physicist Park.

While the few astronomers present watched in horror, some physicists suggested building fleets of nuclear missiles ready to be launched on command against any Earth-bound projectile. Others conjured up wild schemes to extinguish heavenly hazards with antimatter "traps." Edward Teller—the father of the hydrogen bomb—proposed constructing a megabomb thousands of times more powerful than anything that has ever been made. All this prompted one nuclear physicist to shout, according to eyewitnesses, "Nukes forever!"

Laymen and astronomers alike, including Park, find these proposals frightening. Until a potential killer is identified, they say, building giant nuclear missiles is dangerous, costly, and unnecessary. Why? Any celestial body on a collision course with the planet would gradually circle closer and closer over many orbits. If astronomers were looking for it, they would likely have decades or centuries to figure out how to stop it. (Comets—balls of ice and other volatile substances—are an exception to this rule, because their long orbits usually keep them out of range of telescopes. However, it is believed there are far fewer of them.)

"People who are underemployed in the defense industry are using [this issue] . . . to find a cause for their existence," asserts Joseph Veverka of Cornell University, a member of the asteroid detection panel.

Philosophy versus science

Ultimately, how one judges the asteroid hazard depends more on personal philosophy than science. Conservatives in the debate, such as Veverka, focus on the rare nature of meteorite collisions. ("Obviously, heavenly bodies do hit the Earth. But on human time scales, asteroids are not a major problem.") Astronomers like Gehrels, on the other hand, stress that the slight odds of a collision are countered by the terrible consequences of such an event.

There's no simple way to reconcile these views. Researcher Clark Chapman, however, does offer some guidance: For those who board airplanes with trembling knees and hyperventilate every time chemists discover a new carcinogen, killer asteroids are definitely worth worrying about. Otherwise, one shouldn't lose much sleep over them. "I don't," he concludes. PS

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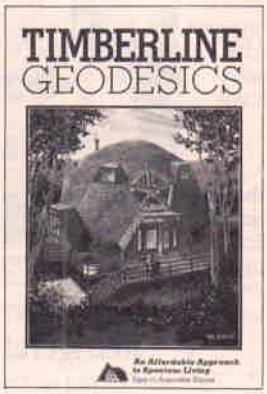

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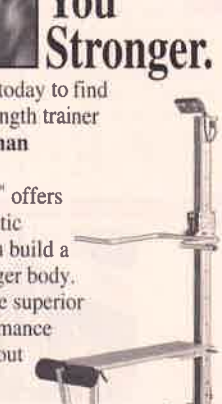

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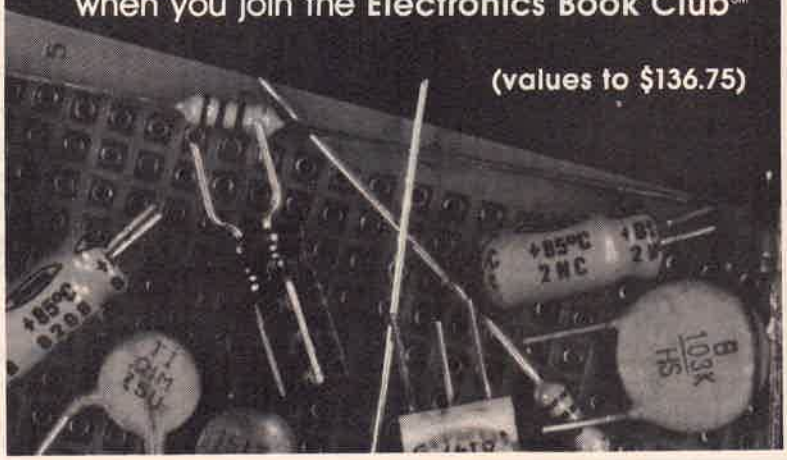

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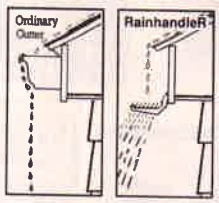

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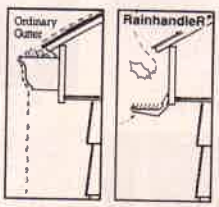

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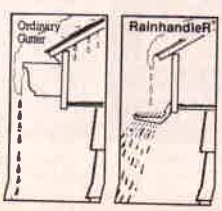

STOP WATER DAMAGE. **RainhandleR** in winter, protects your investment by helping to prevent clogs and ice dams on the roof that *otherwise lead to water rot and leaks.*

Digital photography

[*Continued from page 66*]

tal imaging until last May, when Kodak had invited him, along with several dozen of the world's top photographers, to its Center for Creative Imaging. Naturally, when he later received the *Time* assignment, he asked if he could use CCI's facilities to create the cover.

Heisler synthesized a photograph (on conventional film) he had taken of Ted Turner with the year's most important news images (which he had converted from videotape to digital files) into a computer-manipulated image. The result was a stunning composition of an elongated globe, with the Turner portrait flanked by curve-hugging CNN images ranging from Boris Yeltsin standing on a tank in Red Square during the failed coup to combat footage of Operation Desert Storm.

But the result was achieved at considerable cost in time and computer storage space. At one point, Heisler's Ted Turner/CNN files mushroomed to two gigabytes—two billion bytes—or enough data to fill 5,500 floppy disks, each holding 360 kilobytes.

Editing pixels

To the untrained eye, digital images look exactly like still photographs on a TV screen. A closer inspection reveals that such images are made up of many thousands of pixels. With a paint program such as PhotoFinish, PhotoStyler, ColorStudio, Tempra, Picture Publisher, or Image-In, a user can zoom in on a tiny section of an image—such as a single eyelash—and edit it in order to eliminate defects or alter its color or shape. Every single pixel can be changed, moved, or deleted, and that is the very essence o what digital imaging is all about.

Once in the computer, the only too needed are a computer keyboard an pointing device like a mouse or dr ing tablet. Because the file forr are standard, most professionals fer to switch between two or paint programs, taking advant each one's particular strength might offer better color contro another might make it easier t a mask.

The final step in the digita process is turning the compu into something that others Unlike word processing publishing files, which ar perfectly printed out by ing a couple of keys, outp tal image is far more com

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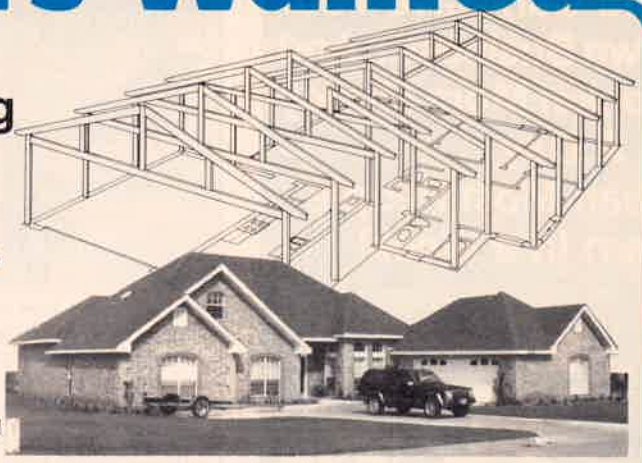

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Digital photography

[*Continued from page 92*]

depth of detail contained in photographic prints. Consequently, their use is limited primarily to making prints and overhead slides for business presentations and color proofs. Most graphics professionals save their image files on removable hard-disk cartridges and then hand them over to a printer, who uploads those files to a computer in order to make the color separations that are used to print photographs in magazines.

Shrinking costs

Most experts predict that digital-imaging technology will become easier to use and less expensive to buy. Already, pictures that could be created only on million-dollar systems a few years ago are being done on personal computers that cost one-fortieth that amount. It's probably only a matter of time before scaled-down systems capable of producing moderate-quality digital images will be available at the local camera store or K Mart for about the price of a VCR.

Eventually, digital imaging may supersede film-based photography in popularity and financial importance, just as the camcorder made 8mm movies obsolete virtually overnight. After all, what amateur photographer doesn't dream of taking quality snapshots with a camera that never needs film? And, with a computer doing all sorts of magical special effects, you could instantly change the color of your car from blue to red or insert Great-Great-Grandfather next to your infant daughter in a family portrait. With digital imaging, it may also be possible to make mess-free color enlargements for pennies per print, display your pictures on a large television set by popping a CD-ROM into its built-in player, and even transmit color images to a friend over an ordinary telephone line.

ARTLab's Robert Schwarzbach is not completely optimistic, however, about the prospects for amateur digital imaging. "Will the average Joe on the street get a digital camera? Probably. But I really don't see him retouching Aunt Mabel's wrinkles. It's craft, it's art. I think it's too complicated for the average person. After all, desktop publishing didn't make us all graphic designers."

But, says Ben Fernandez, chairman of the photography department of New York City's New School for Social Research, "I believe this will be a popular tool. . . . Everybody will be caught up in the techniques, the technology, and the possibilities. It lends itself to the imagination." PS

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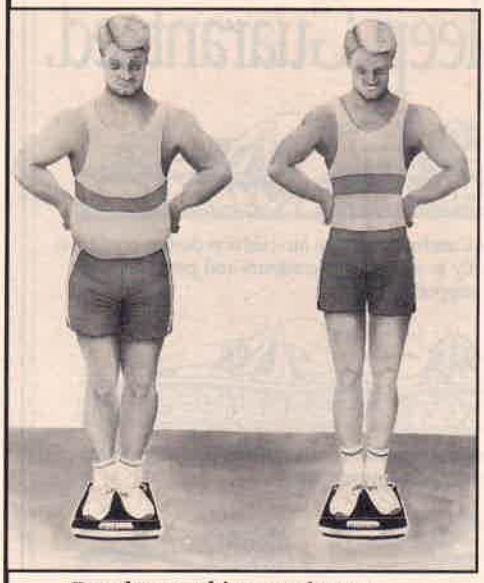

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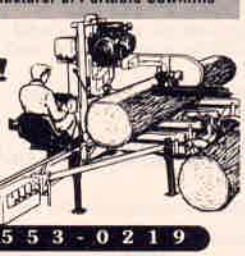

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Crisis in education

[*Continued from page 55*]

project include eminent scientists, educators, cognitive psychologists, teachers, and school administrators.

The project aims to build on past efforts by groups such as the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and the American Chemical Society. The AAAS's Project 2061 (named for the next arrival of Halley's comet) is an attempt to define what science literacy is by setting out a general set of goals for twelfth-graders, including knowledge of key concepts and principles of science. It deemphasizes the amount of detailed information students need to memorize.

The NSTA's Program is called the Scope, Sequence, and Coordination Project. It focuses on grades 7-12, and aims to do away with the traditional "layer cake" approach, in which biology, chemistry, and physics are each taught in successive one-year courses, with no integration. The Scope, Sequence, and Coordination Project calls for spreading the teaching of all the traditional disciplines over six full years, with the connections among them emphasized.

"It became apparent some time ago that we needed a lead organization around that these various groups with uncoordinated programs could coalesce," says Rigden. "The standards we will develop are not a curriculum, but will rather provide a framework in which a curriculum developer and local school districts can work to meet the standards. . . .

"I don't think this will evolve into a set of national curricula. The culture of American schools is so locally based that a real anxiety surfaces whenever the words "national curriculum" are even mentioned. That's why these standards will not define what will go on in the classroom, only define what the objectives for a curriculum in science will be."

If the various science constituencies are indeed successful in uniting on a set of goals for science education in this country, and if they can join the mathematics standards in stimulating the nation's 15,000 school districts to adopt them, then the lofty goal of "first in the world" for U.S. science and math students may yet be achieved. NS

Next month: The final article in this series examines proposals for establishing alternative schools and the role of the new interactive technologies in changing the face of science and math teaching.

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Looking Back...

Sampling a century of POPULAR SCIENCE

25 YEARS AGO — SEPTEMBER 1967

Ford of England has moved a step nearer to the production-line electric car. The Comuta is the first stage in a practical town runabout that is silent and licks air pollution. It is powered by ordinary lead-acid batteries, but is intended eventually to take the long-life sodium-sulfur package being developed by U.S. Ford.

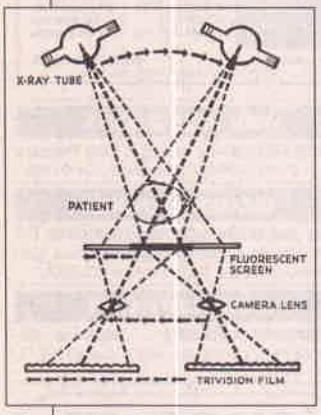
The drive, speed control, and interior heating and ventilating systems of this newborn baby-electric are all cunningly contrived. The chassis has a square-section central backbone with a hollow interior partitioned to serve as twin air ducts for ventilation. Outrigger members carry the batteries, suspension arms, and body.

Only six feet eight inches long overall, the tiny car cruises at 25 mph for a 40-mile range and will do up to 40 mph. With an ultralow center of gravity, it corners like the proverbial billiard table on wheels. The turning circle is a mere 18 feet, and three of these stubby Fords can be parked end-to-curb in the space needed for one ordinary auto.

Ford takes another step toward a production-line electric car with the Comuta.

50 YEARS AGO — SEPTEMBER 1942

A revolutionary new technique, known as Trivision X-Ray, completely eliminates the use of complicated stereoscopic X-ray photography. Surgeons now can use the tridimensional X-ray apparatus in order to determine quickly and accurately the length, breadth, and depth of an object with a single radiograph.



A Trivision X-Ray enables surgeons to determine the length, width, and depth of an object.

The secret of Trivision lies in the use of a specially prepared film embossed with microscopically small ridges, 200 to the inch. Each tiny ridge acts as a perfect lens that focuses light rays from a given object on a critical point on the film emulsion (see illustration). By scanning the subject laterally with the camera, the point of focus on the film is changed to record a panoramic series of picture elements—one for each ridge—that appear to resolve into undistorted panoramic glimpses of the photographed object.

In natural vision, a person perceives depth in an object because each eye sees the subject from a slightly different angle. Trivision films give the same effect because the pictured side contains a series of views that give each eye a different angle of the object. Consequently, an observer can look around and beyond each plane in the picture and get the same effect that he would if he were seeing the object directly.

Trivision radiographs are made by photographing a three-dimensional picture of an object recorded on a fluorescent screen. The X-ray tube, fluorescent screen, lens, and Trivision film are all mounted on an axis that pivots around the subject to be X-rayed. By keeping the screen, lens, and film moving in parallel planes, the image recorded on the fluoroscope is kept in perfect focus.

100 YEARS AGO — SEPTEMBER 1892

It was more than 20 years ago that the late Spencer F. Baird, of the Smithsonian Institution, recognized the advantages of Woods Hole, Mass., as a place to build a laboratory, not only for the investigation of the problems of pure science, but for the study of the many questions of more economic importance connected with this country's supply of edible fish. So, year after year, he and his assistants came here and worked through the summer months.

Some of his assistants made studies of the fish of the region; others collected the other forms of life, for among these we must seek the food of the fish; still others traced the life histories of the injurious as well as of the valuable forms; while still others worked at the problems of artificial hatching. As the work went on it outgrew the limited quarters afforded by the barnlike building on the lighthouse wharf, and so Congress granted the money for the present building, the finest for this type of research of any in the world.

The laboratory is a center for the advancement and diffusion of knowledge, a school for teaching, and a research institute. The instruction given at the laboratory is largely personal. Students also have daily lectures on the general principles of zoology and botany. There are frequently other lectures on subjects of more general scientific interest. These are given by laboratory staff or visiting naturalists, and no lecture course in the country can boast of such subjects treated by such masters.

Students study botany and zoology in laboratories at the expanded facilities at Woods Hole, Mass., on Cape Cod.

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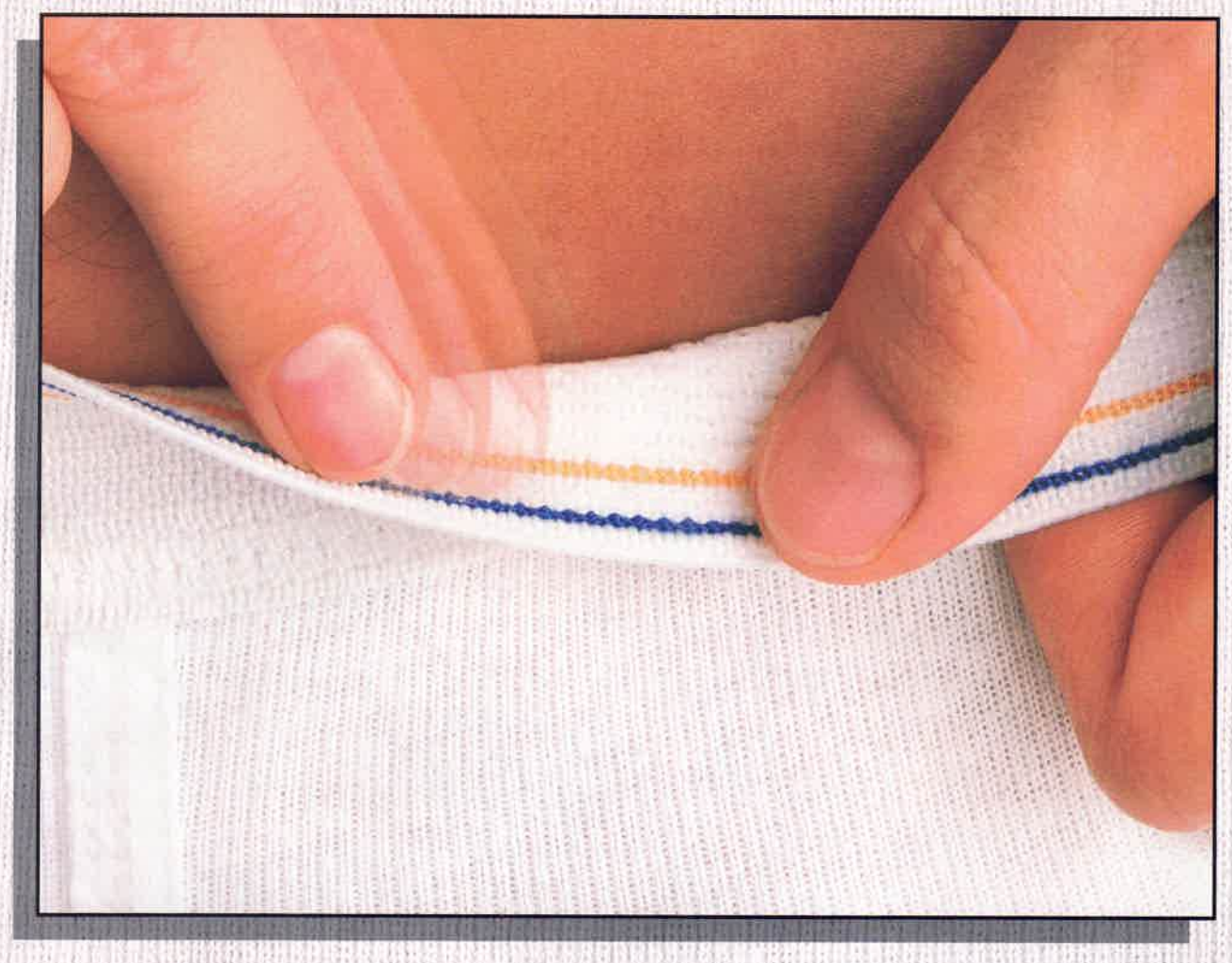

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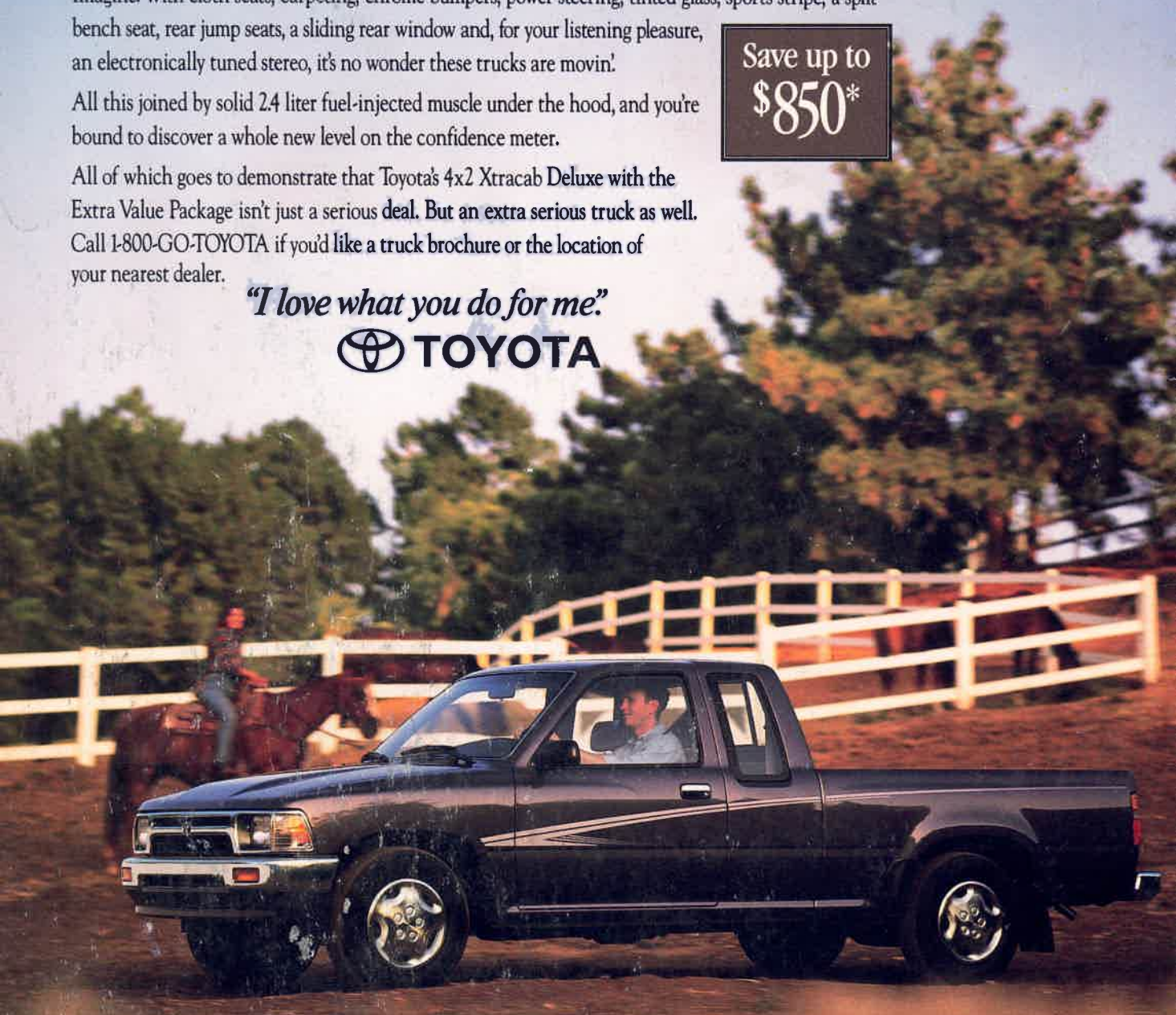

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